



**US Army Corps  
of Engineers**  
Waterways Experiment  
Station

# Site Characterization and Analysis Penetrometer System (SCAPS) Field Investigation at the Building 4020 Site, Aberdeen Proving Ground, Maryland

by William M. Davis, Landris T. Lee, Jr., Jeff F. Powell

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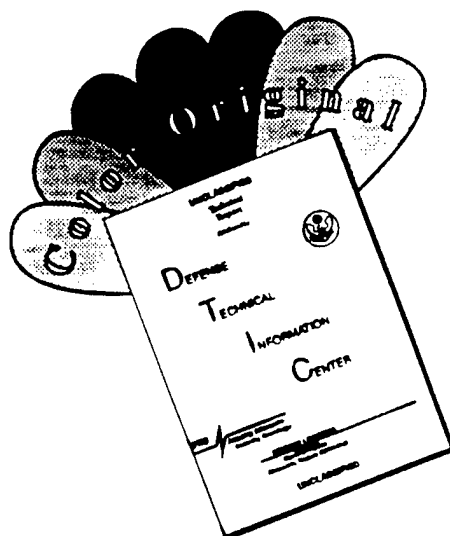
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# **Site Characterization and Analysis Penetrometer System (SCAPS) Field Investigation at the Building 4020 Site, Aberdeen Proving Ground, Maryland**

by William M. Davis, Landris T. Lee, Jr., Jeff F. Powell

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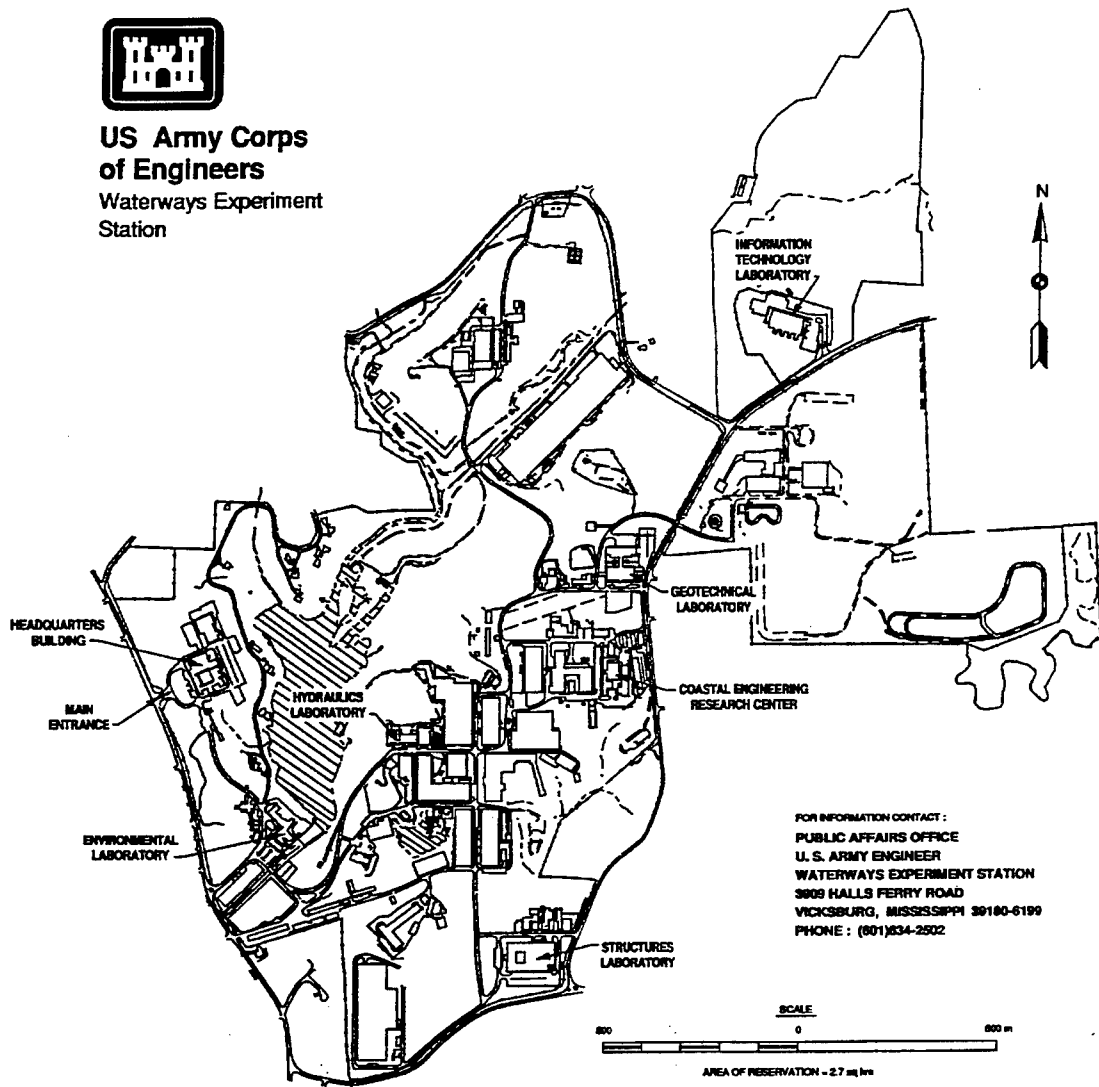
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# Preface

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This report was prepared by the Environmental Laboratory (EL) of the U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. The research was funded under the Tri-Service Site Characterization and Analysis Penetrometer System Program by the U.S. Army Environmental Center, Work Unit A5-3, "Demonstration of Rapid Site Characterization with SCAPS POL Sensor." The Program is managed by Dr. John Cullinane, WES, and Mr. George Robitaille was the Technical Monitor for the U.S. Army Environmental Center. Personnel who cooperated in the execution of the study and the preparation of this report include Dr. William M. Davis, Principal Investigator, Ecosystem Processes and Effects Branch (EPEB), Environmental Processes and Effects Division (EPED), and Mr. Karl Konecny of the Environmental Engineering Division (EED), EL; Mr. Jeff Powell, Instrumentation Services Division (ISD), Information Technology Laboratory (ITL); Mr. Landris Lee, Earthquake Engineering and Geophysics Division (GG), Geotechnical Laboratory (GL); and Mr. Donald Harris, Public Works Division, WES.

This report was reviewed by Dr. Ernesto Cespedes, Chief, Environmental Sensing Branch, EED, and Ms. Cynthia Price, EPED. The report was prepared under the general supervision of Dr. Richard E. Price, Chief, EPEB; Mr. Joseph Curro, Chief, Engineering Geophysics Branch, GG; Mr. Donald L. Robey, Chief, EPED; Dr. Arley G. Franklin, Chief, GG; Dr. John W. Keeley, Director, EL; and Dr. William F. Marcuson III, Director, GL.

At the time of publication of this report, Dr. Robert W. Whalin was Director of WES. COL Bruce K. Howard, EN, was Commander.



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# Conversion Factors, Non-SI to SI Units of Measurement

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Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
gallons (U.S. liquid)	3.7854	liters

# 1 Introduction

---

The U.S. Army Environmental Center sponsored a site characterization conducted by the U.S. Army Engineer Waterways Experiment Station (WES) at a designated petroleum-contaminated site within the U.S. Army Aberdeen Proving Ground (APG), Maryland (Figure 1). The objective was to delineate subsurface petroleum contamination using the petroleum, oil, and lubricant (POL) sensor of the Tri-Service site characterization and analysis penetrometer system (SCAPS). SCAPS with the POL sensor is capable of simultaneously determining subsurface stratigraphy and POL contamination.

SCAPS was deployed at APG from 17 February through 3 March 1995. The site that was characterized is near APG Building 4020 in the vicinity of previously removed #2 fuel oil underground storage tanks (USTs). Data from a total of 61 subsurface penetrations (51 sensing and 10 sampling penetrations) were collected during the time period (Appendix A). The maximum depth of sensor penetration achieved for data collection during the site investigation was 67 ft<sup>1</sup> below ground surface.

In addition to the site investigation using the SCAPS POL sensor, there were demonstrations of SCAPS capabilities for 2 days at the site. A list of demonstration participants is given in Appendix B. A local citizens group, APG personnel, and regulatory representatives attended the demonstrations. These demonstrations were a part of the continuing effort to inform user communities of SCAPS capabilities.

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<sup>1</sup> A table of factors for converting non-SI units of measurement to SI units is presented on page vii.

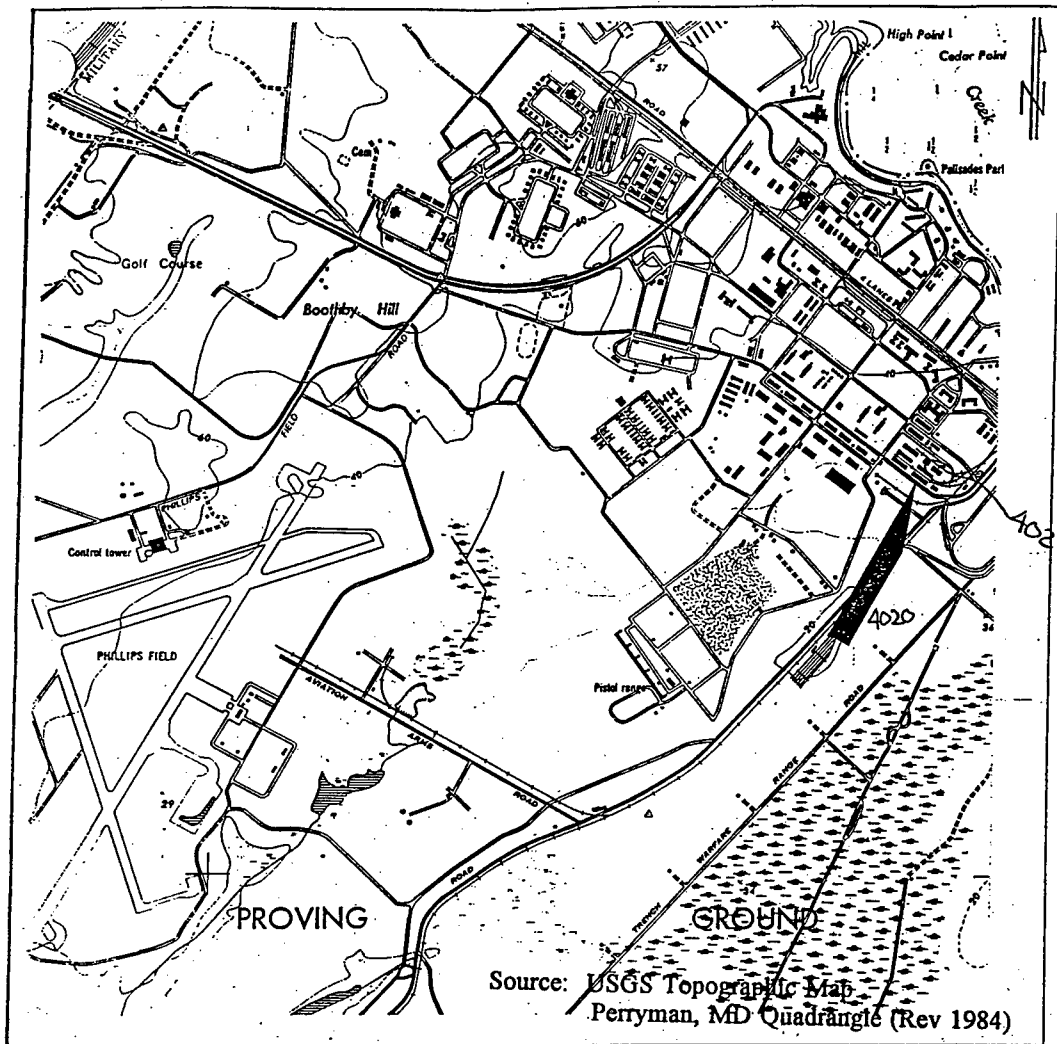


Figure 1. Site map showing Building 4020 within APG

## 2 Site Description

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The SCAPS APG field investigation site is shown in Figure 2. The scope of the investigation initially focused on the area adjacent to Building 4020 and was expanded as the investigation progressed. Previous site investigations have been performed, monitoring wells have been placed, and remediation activities have been accomplished at this site (ENSAT Corporation 1992a,b). The previous investigations identified significant POL contamination near the location of a UST located at the east end of Building 4020.

The site lies approximately 25 ft above mean sea level, and the surface topography does not vary more than 2 ft. Subsurface geology consists of unconsolidated sands, gravels, and clays of the Talbot Formation. A layer of silt/clay extends from the surface to approximately 15 ft below surface. Below 15 ft, a layer of predominately coarse-grained soil is approximately 15 to 20 ft thick. This layer contains an unconfined groundwater aquifer. Perched groundwater present at this site is a result of the highly interbedded clay and gravel lenses in the upper silt/clay layer. The general groundwater flow direction is to the northeast as determined from monitoring well logs.

Three monitoring wells have been used as product recovery systems at this site. The monitoring well labeled MW-1, located between Buildings 4040 and 4027, was pumped to recover fuel product into a 550-gal storage tank (ENSAT Corporation 1992a). Another well labeled MW-1, located just south of the southeast corner of Building 4020, was also pumped to recover fuel product into a 550-gal storage tank (ENSAT Corporation 1992b). It should be noted that Figure 2 includes two wells labeled MW-1; they were installed and labeled separately during two previous investigations. Those two recovery systems were later removed on the assumption that the free POL product had been completely recovered. However, a recovery system is presently operating at MW-11 located between Buildings 4024 and 4025.

The areas around Buildings 4020, 4022, 4024, 4027, and 4040 were chosen for the SCAPS investigation because the area had previously known POL contamination. The reappearance of free product in MW-1 near Building 4020 warranted reassessment of the source of the contamination. The SCAPS investigation was expanded to include the areas around Buildings 4031 and 4035 when SCAPS penetration #32 detected significant POL contamination. There was no previous knowledge of POL contamination in those areas.

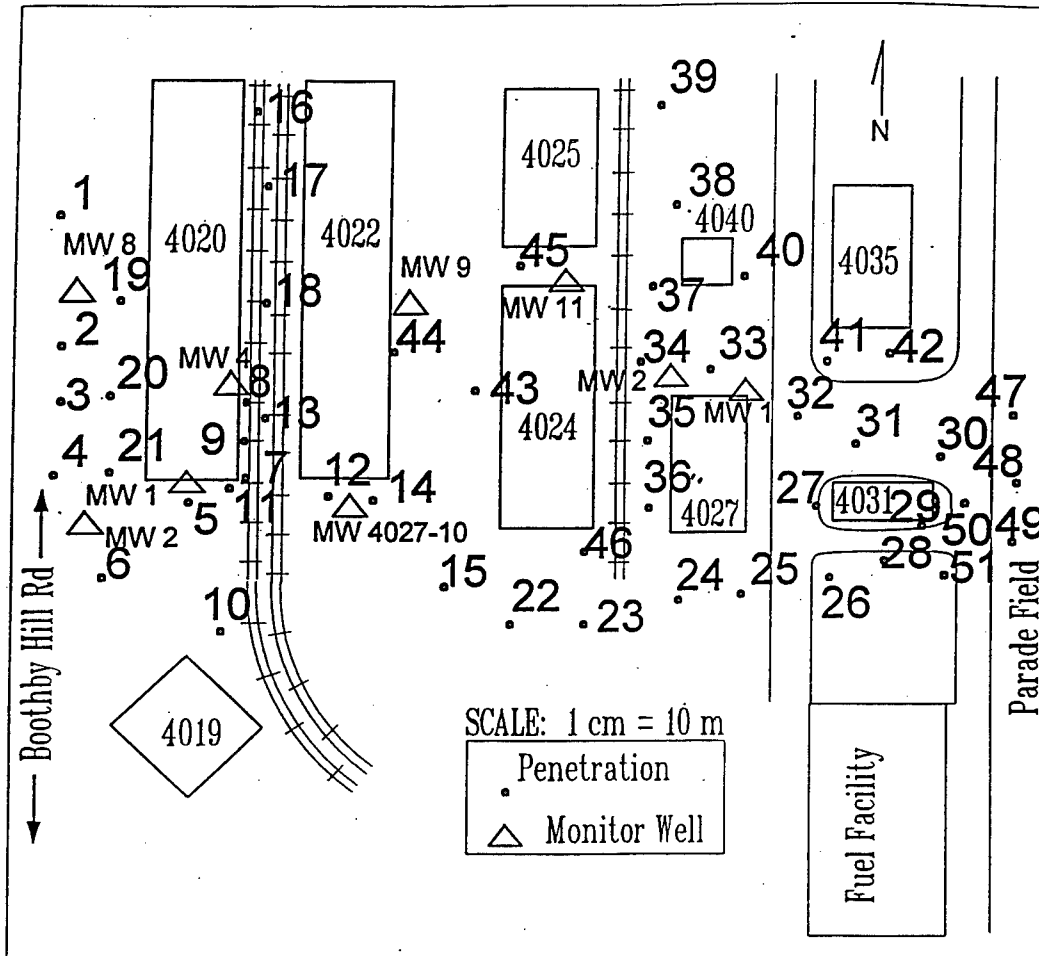


Figure 2. SCAPS investigation site near Building 4020

# 3 Investigation Equipment and Procedures

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## General Operations

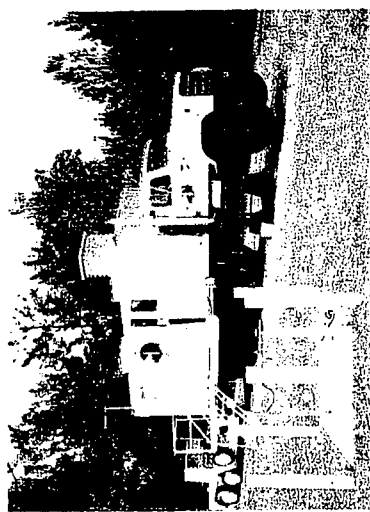
SCAPS consists of the cone penetrometer truck, enclosed support trailer containing the decontamination wash water system and grout pumping system, and a mobile analytical laboratory van. Figure 3 shows the SCAPS vehicle and support trailer. The SCAPS sensors used at APG were the soil classification sensor and the laser-induced fluorescence (LIF) sensor combined to form the POL sensor. It should be noted that the soil classification sensor used in the SCAPS is operated in accordance with procedures described in American Society for Testing and Materials (ASTM) Method D3441 (ASTM 1995). For more details, the reader is referred to previous descriptions (Olson and Farr 1986; Lee et al. 1993).

A digging clearance was obtained prior to performing any penetrations in order to comply with APG regulations and the SCAPS APG Safety Plan. The soil classification sensor consists of strain gauges mounted in the penetrometer cone tip and sleeve. These gauges are calibrated at the beginning of each investigation and checked periodically. The LIF sensor is calibrated using an aqueous solution of Rhodamine before and after each penetration event to monitor LIF system response and document any system drift. The standard operating procedures for the SCAPS POL sensor have been described previously (Aptiz et al. 1992; Lee et al. 1994).

Safety precautions involved protection from damage and contamination. Several penetrations required prepushing a few inches to avoid sensor probe damage due to surfaces such as asphalt pavement or gravel. After the measurements for each penetration were completed, the penetration holes were grouted through the probe tip during sensor retraction to prevent cross-strata contamination, and the push rods were decontaminated with the onboard hot water wash (Koester et al. 1993).

Real-time sensor response for the soil classification and LIF sensors is plotted during each penetration. These data allow the operator to observe the soil classification and fluorescence response as the sensors are advanced into

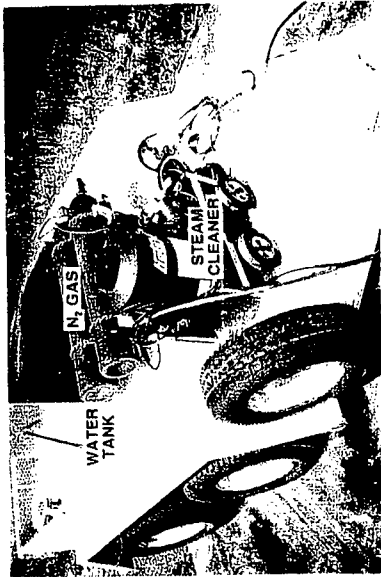
# **SITE CHARACTERIZATION AND ANALYSIS PENETROMETER SYSTEM (SCAPS)**



**SCAPS Truck and Grout Trailer  
(Monitoring Well in Foreground)**



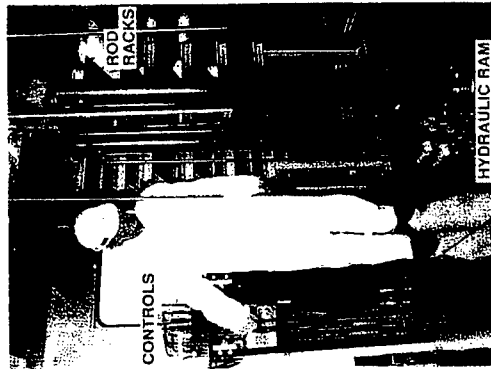
**Cone Penetrometer  
With Sensor Package**



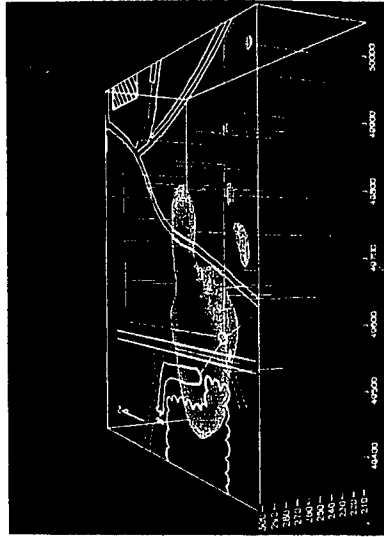
**Grout Trailer**



**Data Acquisition/Processing  
Compartment**



**Hydraulic Operations  
Compartment**



**Three-Dimensional Contaminant  
Visualization**

**Figure 3. The SCAPS system**



the soil. The sensor data were then plotted as a function of depth for informative visualization (Figure 4).

## Penetrometer Fluorescence Verification

The operating procedures for the SCAPS POL sensor included verification of the fluorescence response for a fraction of the data collected at a particular site. The verification samples were used to confirm the presence of POL contamination detected by the LIF sensor as well as to build a verification database for regulatory acceptance. Soil samples were taken with direct push soil samplers advanced to the sampling depth using the SCAPS truck. Soil samples were obtained at depths of interest approximately 1 ft horizontally offset from corresponding sensor penetrations.

The verification samples were homogenized in the field by mixing with a stainless steel spatula in a stainless steel pan. The samples were placed in precleaned 250- or 500-mL glass jars with Teflon-lined caps and stored at 4 °C until analyzed. The SCAPS LIF response was obtained for each homogenized soil sample in the field by pressing the soil against the sapphire window of the SCAPS POL sensor probe and collecting spectra (Lee et al. 1994). The procedure was carried out in triplicate for each soil sample investigated. Soil analyses for total recoverable petroleum hydrocarbons (TRPH) were performed onsite using a field portable method (Davis, Jones, and Porter 1995) and in the WES analytical laboratory using U.S. Environmental Protection Agency (EPA) Method 418.1 (EPA 1984). Verification samples were also analyzed for polynuclear aromatic hydrocarbons (PAHs) by EPA Method 8270.

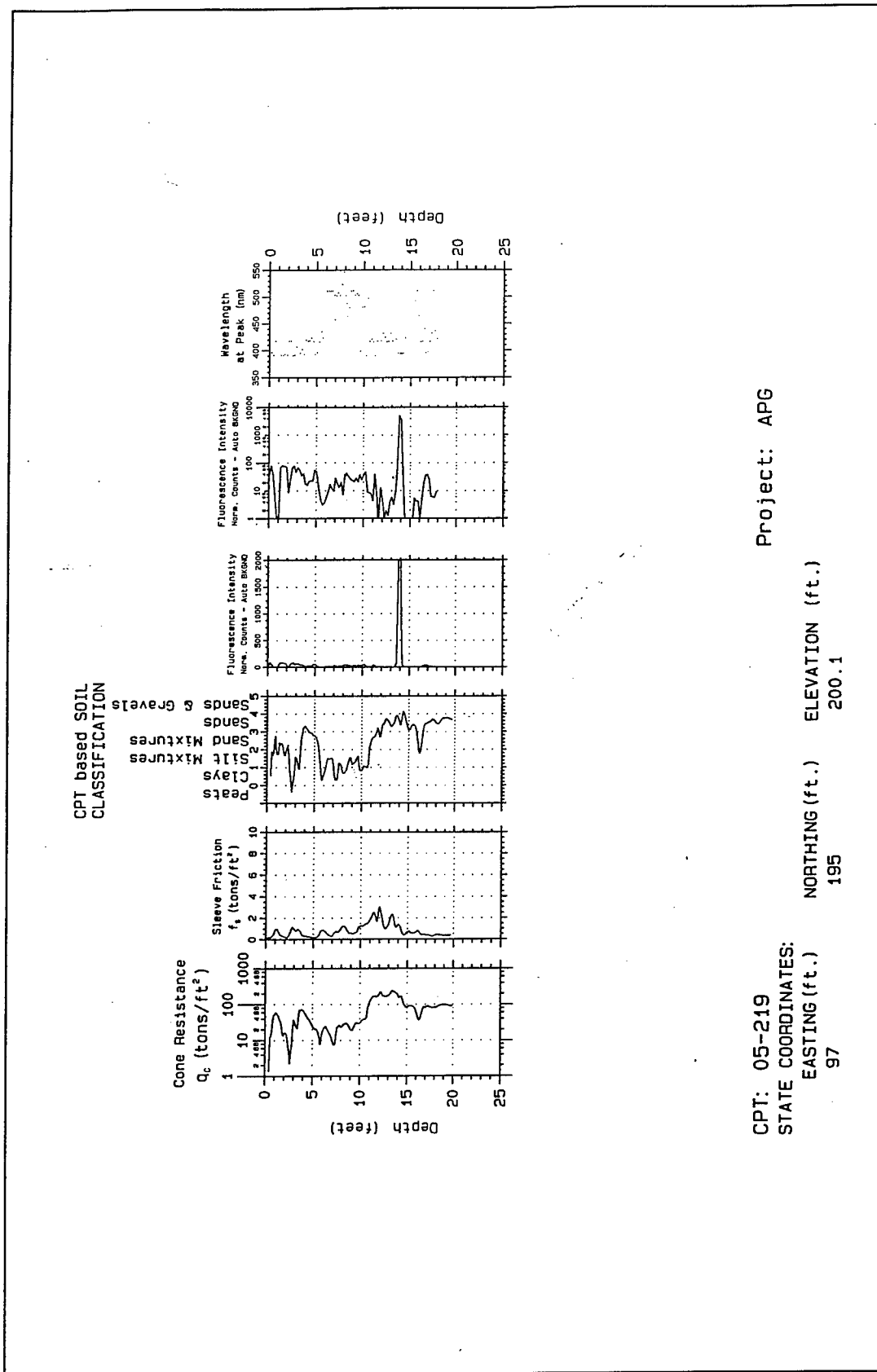


Figure 4. Typical SCAPS panel plot (from penetration #5 near Building 4020)

## 4 Results and Discussion

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A total of 51 POL sensor penetrations were completed over 12 days. During the same time period, 10 soil sampling penetrations were completed, with 20 verification soil samples retrieved. Three-dimensional (3-D) computer models of both the soil stratigraphy and POL sensor response were generated during the final 3 days of data collection, enabling onsite 3-D visualizations of subsurface site conditions (Figures 5, 6, and 7). The data for Figure 7 are the same as for Figure 6, but replotted to enhance the high-intensity areas.

### Soil Classification Measurements

The site soils consist of gravels, sands, clays, and silts, all highly interbedded. The soil classification sensor data agreed with the soil classification and lithology determined previously (ENSAT Corporation 1992a,b). In general, the fine-grained material to a depth of 15 ft below ground surface (BGS) was underlain by coarse-grained material approximately 15 to 20 ft thick. Below that was another fine-grained material, which appears to be an aquitard based on visual identification of soil sample moisture content. The top of that fine-grained layer (approximately 35 to 38 ft BGS) contains partially decomposed woody material (tree stems) that was not water saturated. The woody material was initially noticed from the amplified LIF response as the probe penetrated the material and was confirmed with subsequent verification soil sampling analyses.

The soil classifications assigned using the SCAPS sensor are those designated in ASTM Method D3441. The soil classification data were plotted as a function of depth and used to generate a 3-D computer model of the site stratigraphy. The site stratigraphy generally conformed to the soil classification and lithology determined from the previous soil borings. However, it should be noted that the SCAPS soil classification sensor stored a data point for every 4 cm the sensor advanced. The high density of data points for each SCAPS push and the large number of penetrations achievable (e.g., six per day) provide much higher resolution stratigraphic mapping than conventional soil boring techniques (EPA 1995).

# Aberdeen Proving Ground Soil Stratigraphy

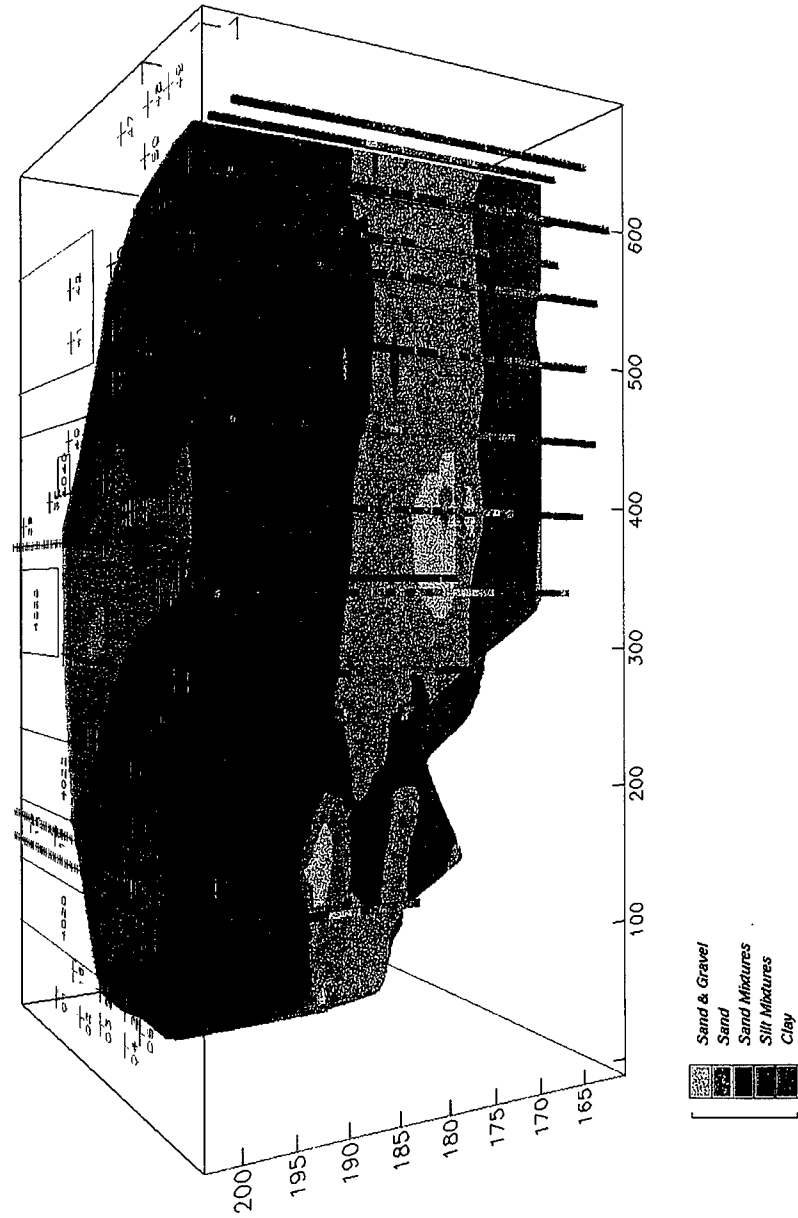


Figure 5. View of site soil stratigraphy

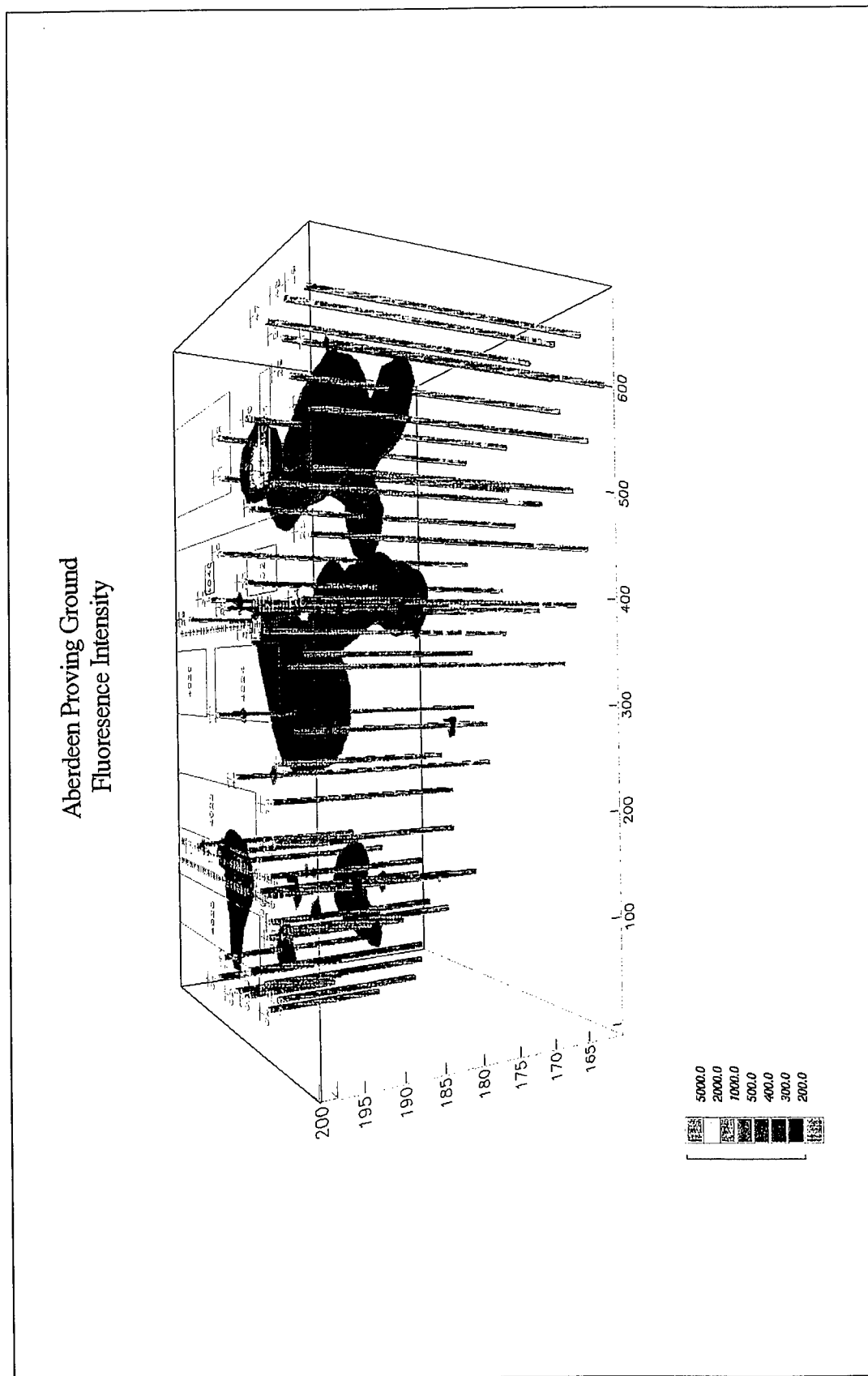


Figure 6. View of SCAPS POL sensor response, low intensity

# Aberdeen Proving Ground Fluorescence Intensity

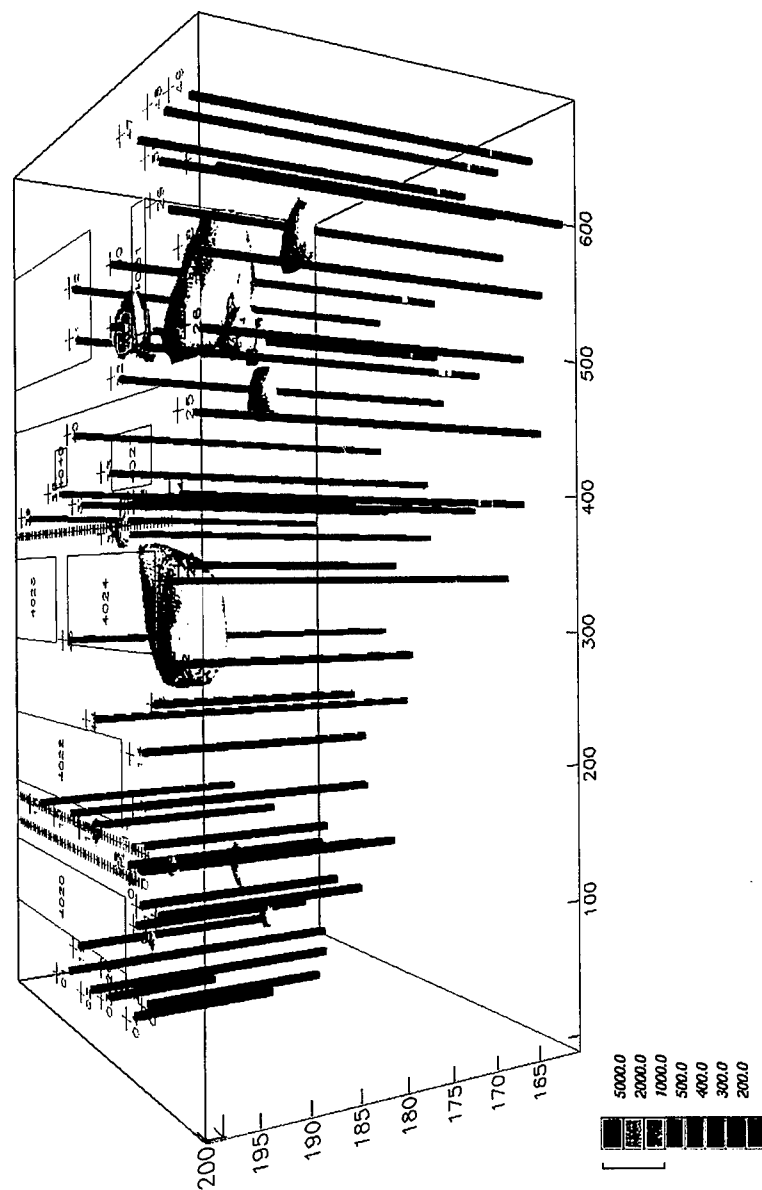


Figure 7. View of SCAPS POL response, high intensity

## Subsurface Petroleum Detection Using the SCAPS POL Sensor

The SCAPS POL sensor was used to obtain subsurface fluorescence data concurrently with the data collected by the soil classification sensor. These data were plotted real-time during each SCAPS penetration push. After completing a SCAPS push, the data were printed and archived (Appendix A). The locations of penetrations at a particular site were based on historical data and on data generated onsite by SCAPS, allowing the site engineer flexibility in locating penetrations to yield the most informative data.

Initial SCAPS investigations at the APG site were concentrated in the area around the south end of Building 4020 because a previous study indicated POL contamination associated with the #2 heating oil UST located in this area. Previous investigation indicated free product around MW-1, which had been installed at the previously removed UST location. An additional area of POL contamination was identified near MW-8, where elevated organic vapor analysis (OVA) results were noted during well installation (ENSAT Corporation 1992b).

SCAPS penetrations in the areas around MW-1, MW-4, and MW-8 confirmed the previous findings (Appendix A, Figures A5, A8, and A19). SCAPS penetration #5 detected a narrow band of intense fluorescence response approximately 14 ft BGS, consistent with the previously reported free product detected in MW-1. Bands of less intense but significant fluorescence response was detected by penetration #19 (adjacent to MW-8). The SCAPS data indicated low level fluorescence from the surface to 5 ft BGS, and contamination appeared again at 7.5 ft BGS and continued to approximately 20 ft BGS. The OVA analyses performed during the installation of MW-8 indicated elevated readings from 4 to 21 ft BGS.

Slightly elevated OVA response was noted near the surface during installation of MW-4 (ENSAT Corporation 1992b). Fluorescence response detected by the SCAPS POL sensors in this area also indicated low level POL contamination near the surface. SCAPS penetration #8 (closest to MW-4) detected elevated fluorescence from 0.5 to 3 ft BGS. It should be noted that all the penetrations along the railroad siding between Buildings 4020 and 4022 indicated low fluorescence response near the surface (Appendix A, Figures A7, A9, A13, A16, and A17). The detection of POL contaminants near the surface, all along the railroad siding may indicate fuel leaking from train engines or leached creosote from crossties as possible sources in this area.

Another area investigated was near Buildings 4024, 4025, and 4027. A previous study of the area north of Building 4027 had indicated free product POL contamination, undoubtedly due to the previously removed #2 heating oil UST (ENSAT Corporation 1992a). A recovery well was installed at MW-1 and the product was recovered. Subsequent soil borings and monitoring wells confirmed that the migration of contaminants was very limited (ENSAT

Corporation 1992a). The SCAPS POL sensor penetrations in the area indicated very low or nondetectable POL contamination (Appendix A, Figure A33). However, penetration #45 (near MW-11) on the north end of Building 4024 detected extremely high level POL contamination from 12 to 17 ft BGS (Appendix A, Figure A45). These data are consistent with previous investigations that identified free product in this area.

The third area investigated was east of Building 4027, south of Building 4035, and all around Building 4031. That area was investigated because significant fluorescence response was noted during SCAPS penetration #30 (Appendix A, Figure A30). The data indicated a very intense band of POL contamination from 10 to 15 ft BGS. Penetration #30 was performed to investigate the possible down-gradient migration of free product from the UST that had been located north of Building 4027. However, the low levels of contamination detected in the areas investigated around building 4027 and high contaminant levels detected in penetration #30 suggested an alternate source of contamination.

Based on the results of penetration #30, the area of the parking lot to the north of Building 4031 was investigated. The suspected source appears to be in the vicinity of SCAPS penetration #31 (just west of penetration #30). That penetration revealed high fluorescence from the surface down to about 15 ft BGS (Appendix A, Figure A31). Subsequent penetrations around Building 4031 delineated the extent of POL contamination in the area (visualized in Figure 5). Penetration #29 was located to the south of Building 4031 and detected significant fluorescence response in a sandy layer from 13 to 14 ft BGS. Similar levels of contamination were also detected northwest of the building in a sandy layer 15 to 17 ft BGS during penetration #32 (Appendix A, Figure A32).

The other penetrations performed around Building 4031 detected no significant fluorescence response, indicating a lack of POL contamination (Appendix A, Figures A26, A27, A28, A42, A47, A48, A49, A50, and A51). The contamination around Building 4031 thus appears to be relatively localized, as was the case for the leaking USTs at Buildings 4020 and 4027 (ENSAT Corporation 1992a,b). It should be noted that the contamination detected in penetrations #30 and #31 was in soil strata that consisted of silts and clays, while the contamination detected in penetrations #29 and #32 appear at the top of the sand layer, just below the clay/sand interface. These results indicate that the localized contamination near penetration #31 has barely seeped onto the groundwater of the surficial aquifer. Data from the SCAPS penetrations performed to the east of Building 4031 (Figure 2, and Appendix A, Figures A47, A48, A49, and A50) indicate that the contamination has not migrated across the street into the parade grounds.

It should be noted that 14 SCAPS penetrations were performed in 2.5 working days and totally delineated the extent of the POL plume in the vicinity of Building 4031. The investigation in the vicinity of Building 4031 completed the SCAPS POL sensor investigation at the APG site. A total of



51 sensor penetrations were performed during a period of 12 days. Three different areas of POL contamination were investigated during this time.

## POL Sensor Verification

In addition to the SCAPS POL sensor penetrations, 10 penetrations were performed with direct push soil sampling tools to obtain 20 samples for POL sensor verification. Standard verification soil sampling procedures were followed (Koester et al. 1993; Lee et al. 1994). The samples were analyzed onsite for TRPH and offsite at the WES analytical laboratory for TRPH and PAH. The soil samples were also analyzed for fluorescence response by pressing the soil against the probe window and collecting the fluorescence emission.

Verification soil samples were collected at locations 0.5 to 1 ft horizontally offset from selected sensor penetrations. Soil samples were obtained at depths with high, medium, low, and no fluorescence response (Table 1). Soil samples were named according to the POL sensor penetration being verified (e.g., soil sample 29S1 was the first soil sample obtained adjacent to POL sensor penetration #29).

The results show strong correlations between the fluorescence response of the samples, the TRPH (Figure 8), and the total PAH minus naphthalenes (NAPH) (Figure 9). The POL sensor response results from fluorescence emission of the PAH components heavier than naphthalene present in petroleum products (Aptiz et al. 1992). Therefore, it is expected that the strongest correlation would be between the PAH components heavier than naphthalene. For a particular petroleum product, there is a correlation between the TRPH for that product and the PAH concentration (Lee et al. 1994; Davis, Jones, and Porter 1995). Thus, a site contaminated with a single POL product should exhibit a correlation between the TRPH and the POL sensor response.

The influence of the heavier PAHs can be seen in the results of the validation samples collected during the investigation at the APG site (Table 2). The results indicated that the strongest correlation between POL sensor fluorescence response and other POL measures was observed for the total PAH minus NAPH ( $r^2 = 0.92$ ). The correlation between the total PAH (including NAPH) and POL sensor response is much weaker ( $r^2 = 0.79$ ) and is even weaker for NAPH alone ( $r^2 = 0.69$ ). The correlations between both TRPH measures and the POL sensor response were strong ( $r^2 = 0.91$  for EPA Method 418.1,  $r^2 = 0.89$  for field portable method, Table 2). There is a very strong correlation between the EPA Method 418.1 and the field portable method TRPH ( $r^2 = 0.99$ ) (Davis, Jones, and Porter 1995).

Soil samples were also obtained to verify apparently anomalous POL sensor responses. Non-POL fluorescence has been documented to occur due to the presence of fluorescent minerals (Lee et al. 1994). Soil samples were obtained at all locations that yielded POL sensor fluorescence response in a

**Table 1**  
**APG Validation Sample Results**

Sample Name	Sampling Depth BGS ft	POL Sensor Response Counts	TRPH Field Method mg/kg	EPA Method 418.1 mg/kg	Total PAH mg/kg	Total PAH-NAPH mg/kg	Total NAPH mg/kg
05S2	13.5-15.0	5,695.0	7,337	7,500	31.9	15.77	16.13
05S1	13.6-14.4	104.3	<10	<25	<0.41	<0.41	<0.41
09S1	3.83-4.17	145.3	16	<25	<0.41	<0.41	<0.41
17S1	1.0-1.75	167.3	<10	<25	0.56	0.52	0.04
17S2	4.0-5.0	141.3	<10	<25	<0.41	<0.41	<0.41
17S3	6.5-7.5	115.7	<10	<25	<0.41	<0.41	<0.41
19S1	7.5-8.25	136.3	<10	<25	<0.41	<0.41	<0.41
19S2	8.25-9.0	223.0	10	<25	<0.41	<0.41	<0.41
27S1	32.0-33.5	218.7	<10	<25	<0.41	<0.41	<0.41
27S2	33.5-34.5	137.7	11	200	<0.41	<0.41	<0.41
29S1	13.5-13.8	15,594.0	51,444	62,000	407.87	105.87	302.0
29S2	13.8-14.4	2,920.0	5,944	7,500	49.49	14.27	35.22
31S1	3.5-4.0	357.7	152	370	2.65	1.17	1.48
31S2	4.25-5.0	415.7	745	2,000	15.91	5.59	10.32
31S3	11.5-12.0	5,341.7	4,681	8,400	55.19	20.98	34.21
38S1	18.0-18.7	171.7	<25	<25	<0.41	<0.41	<0.41
38S2	32.75-34	205.0	<25	<25	<0.41	<0.41	<0.41
45S1	13.0-14.0	144.3	87	66	0.089	0.089	<0.41
45S2	17.0-17.83	194.7	598	920	1.938	1.29	0.648
53S1	32.6-33.4	156.3	32	52	0.435	0.215	0.22

strata or geologic location where POL contamination would not be expected. For example, there was often significant fluorescence response at 31 to 35 ft BGS (Appendix A, Figures A24, A27, A38, A40, A44, A47, A48, and A51). The fluorescent responses all occurred at a sand/clay interface and were located at depths significantly below the top of the surficial aquifer.

Based on these observations, it was suspected that fluorescence at these locations was not due to POL contamination. Verification soil samples obtained at these locations (Table 1, samples 27S1, 27S2, and 38S2) confirmed the lack of POL contamination at these locations. In addition, samples 27S2 and 39S2 both contained pieces of wood that yielded significant fluorescence response when analyzed. Naturally occurring soil organic matter is

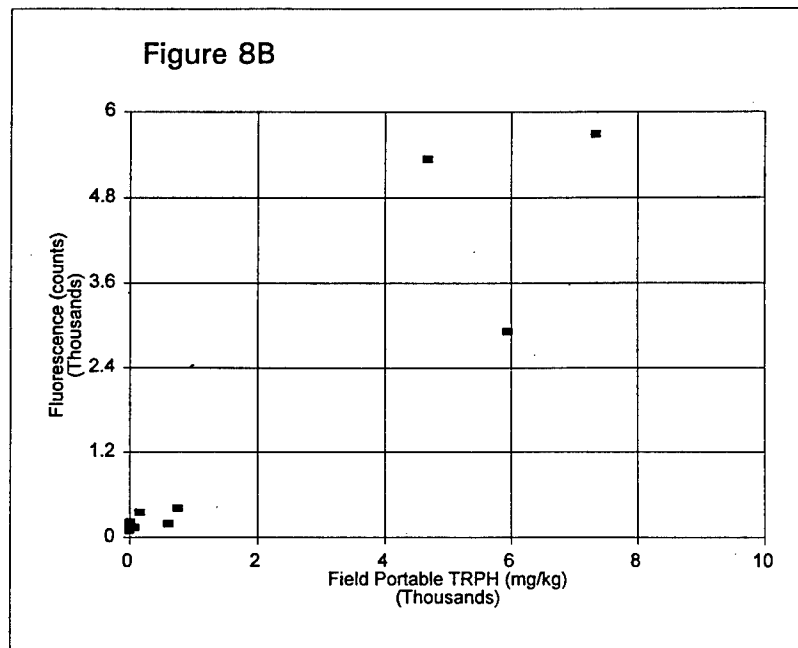
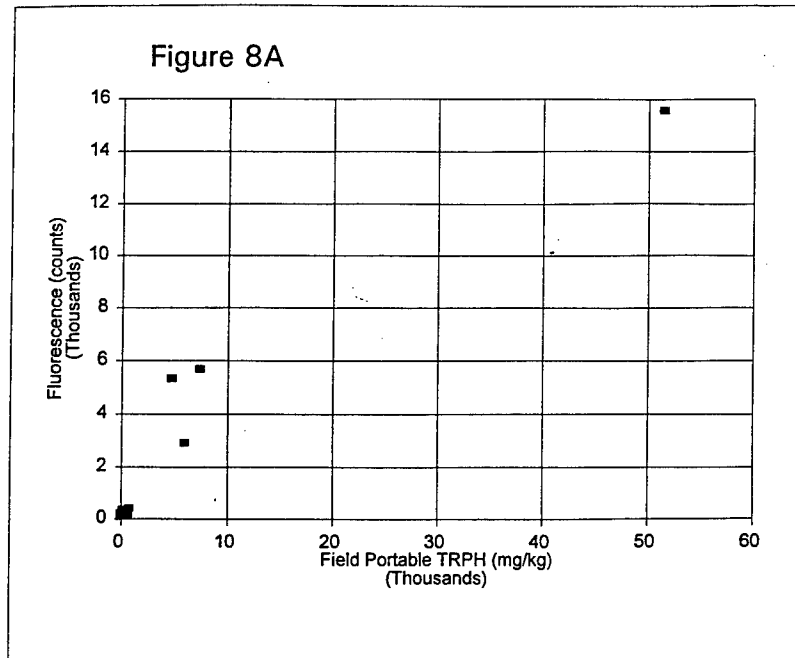


Figure 8. Comparison between TRPH and POL sensor response (8A contains all data presented in Table 1; 8B is an expanded view of the low concentration region of 8A)

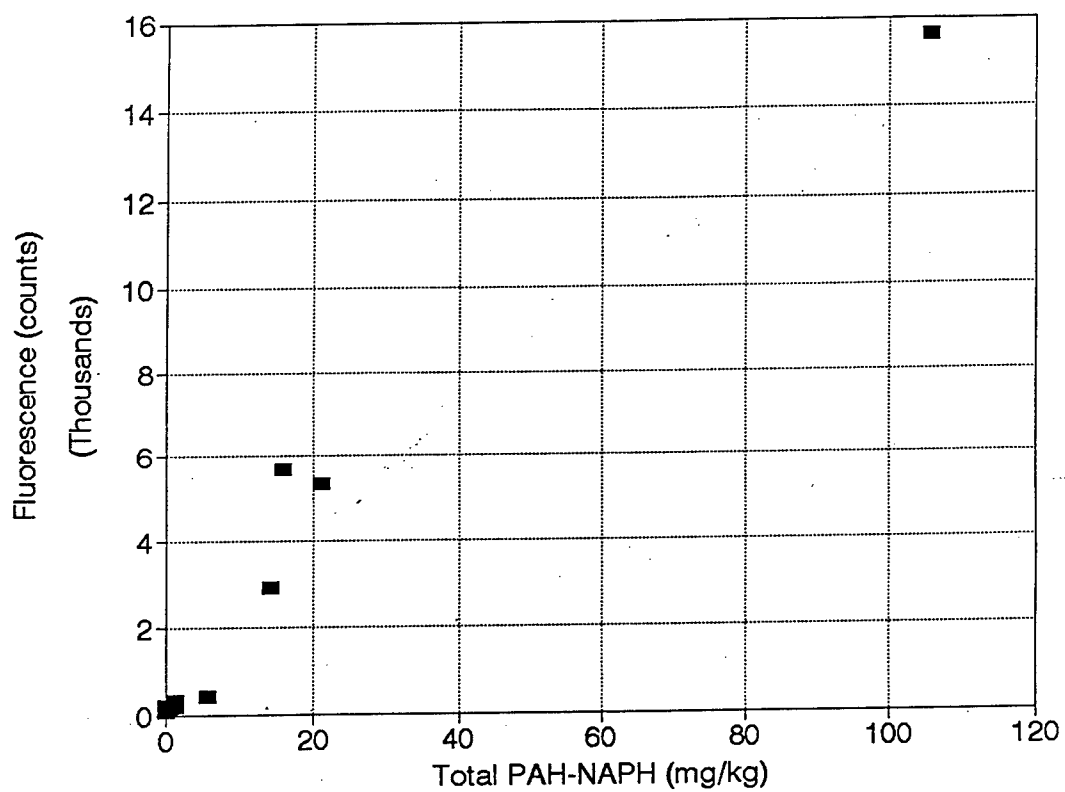


Figure 9. Comparison between PAH-NAPH and POL sensor response

<b>Table 2</b> <b>Aberdeen Proving Grounds Validation Soil Sample Results</b>			
<b>EPA Method 418.1 Versus POL Sensor Response</b>		<b>Total PAH Versus POL Sensor Response</b>	
<b>Regression Output</b>		<b>Regression Output</b>	
Constant	72.77089	Constant	150.9029
Std Err of Y Est	541.1965	Std Err of Y Est	820.0173
R Squared	0.909438	R Squared	0.792087
No. of Observations	19	No. of Observations	19
Degrees of Freedom	17	Degrees of Freedom	17
X Coefficient(s)	0.577941	X Coefficient(s)	89.30408
Std Err of Coef	0.044233	Std Err of Coef	11.0969
<b>TRPH Field Method Versus POL Sensor Response</b>		<b>Total PAH-NAPH Versus POL Sensor Response</b>	
<b>Regression Output</b>		<b>Regression Output</b>	
Constant	139.2433	Constant	69.76189
Std Err of Y Est	589.4408	Std Err of Y Est	512.7827
R Squared	0.892572	R Squared	0.918698
No. of Observations	19	No. of Observations	19
Degrees of Freedom	17	Degrees of Freedom	17
X Coefficient(s)	0.731322	X Coefficient(s)	261.5653
Std Err of Coef	0.061535	Std Err of Coef	18.87212
		<b>Total NAPH Versus POL Sensor Response</b>	
		<b>Regression Output</b>	
		Constant	223.75179
		Std Err of Y Est	993.9005
		R Squared	0.694563
		No. of Observations	19
		Degrees of Freedom	17
		X Coefficient(s)	129.6494
		Std Err of Coef	20.85217

known to fluoresce (Christman and Gjessing 1983; Thurman 1985). The fluorescence response at these locations and depths was determined onsite with the TRPH analysis to be due to naturally occurring organic matter.

## 5 Summary and Conclusions

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The SCAPS POL sensor site investigation at Aberdeen Proving Ground demonstrated the rapid site characterization capabilities of SCAPS. The investigation at Buildings 4020, 4025, and 4027 confirmed the presence of previously known POL contamination. The SCAPS penetrations in these areas confirmed the localized nature of the contamination in these areas.

SCAPS penetrations in the vicinity of Building 4031 identified an area of previously unknown POL contamination. The contamination in this area was also shown to be relatively localized. The ability to locate data collection points (SCAPS POL sensor penetrations) based on data generated onsite in real-time was demonstrated to greatly accelerate the delineation of the POL plume in the vicinity Building 4031. The POL contamination in this area was mapped with 14 SCAPS sensor penetrations, requiring approximately 2.5 working days.

Soil samples obtained for POL sensor verification indicated a strong correlation between conventional methods of POL measurement and the SCAPS POL sensor response.

# References

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- Aptiz, S. E., Borbridge, L. M., Theriault, G. A., and Lieberman, S. H. (1992). *Analus* 20, 461-474.
- American Society for Testing and Materials (ASTM). (1995). *Annual book of ASTM standards*. 04.08 (D-3441), Philadelphia.
- Christman, R. F., and Gjessing, E. T. (1983). *Aquatic and terrestrial humic materials*. Ann Arbor Science Publishers, Ann Arbor, MI.
- Davis, W. M., Jones, P., and Porter, B. (1995). "Field portable petroleum analysis for validation of the site characterization and analysis penetrometer system petroleum, oil and lubricant sensor." *Proceedings of the fourth international symposium of field screening methods for hazardous waste and toxic chemicals*. U.S. Environmental Protection Agency, Las Vegas, NV.
- ENSAT Corporation. (1992a). "Site characterization APG-Building 4027 Aberdeen, Maryland ENSAT Job #91A-00040," Culpeper, VA.
- \_\_\_\_\_. (1992b). "Site characterization APG-Building 4020 Aberdeen, Maryland ENSAT Job #91A-00045," Culpeper, VA.
- Koester, J. P., Lee, L. T., Powell, J. F., and Goodson, R. (1993). "Operators manual for the site characterization and analysis penetrometer system," U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Lee, L. T., Chrestman, A. M., Douglas, D. H., Powell, J. F., and Malone, P. G. (1993). "Site investigations with the site characterization and analysis penetrometer system at Fort Dix, New Jersey," Technical Report GL-93-17, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Lee, L. T., Davis, W. M., Goodson, R. A., Powell, J. F., and Register, B. A. (1994). "Site characterization and analysis penetrometer (SCAPS) field investigation at the Sierra Army Depot, California," Technical Report GL-94-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

- Olsen, R. S., and Farr, J. V. (1986). "Site characterization using the cone penetrometer test." *Proceedings of the American Society of Civil Engineers Conference on in-situ testing in geotechnical engineering*. New York.
- Thurman, E. M. (1985). *Organic geochemistry of natural water*. Kluwer Academic Publishers, Hingham, MA.
- U.S. Environmental Protection Agency. (1984). "Test methods for evaluating solid waste; Physical/chemical methods," SW-846 Third Edition, Washington, DC.
- \_\_\_\_\_. (1995). "Tri-Service SCAPS technology innovative technology evaluation report," Office of Research and Development, Washington, DC.



# **Appendix A**

## **SCAPS POL Sensor Panel Plots**

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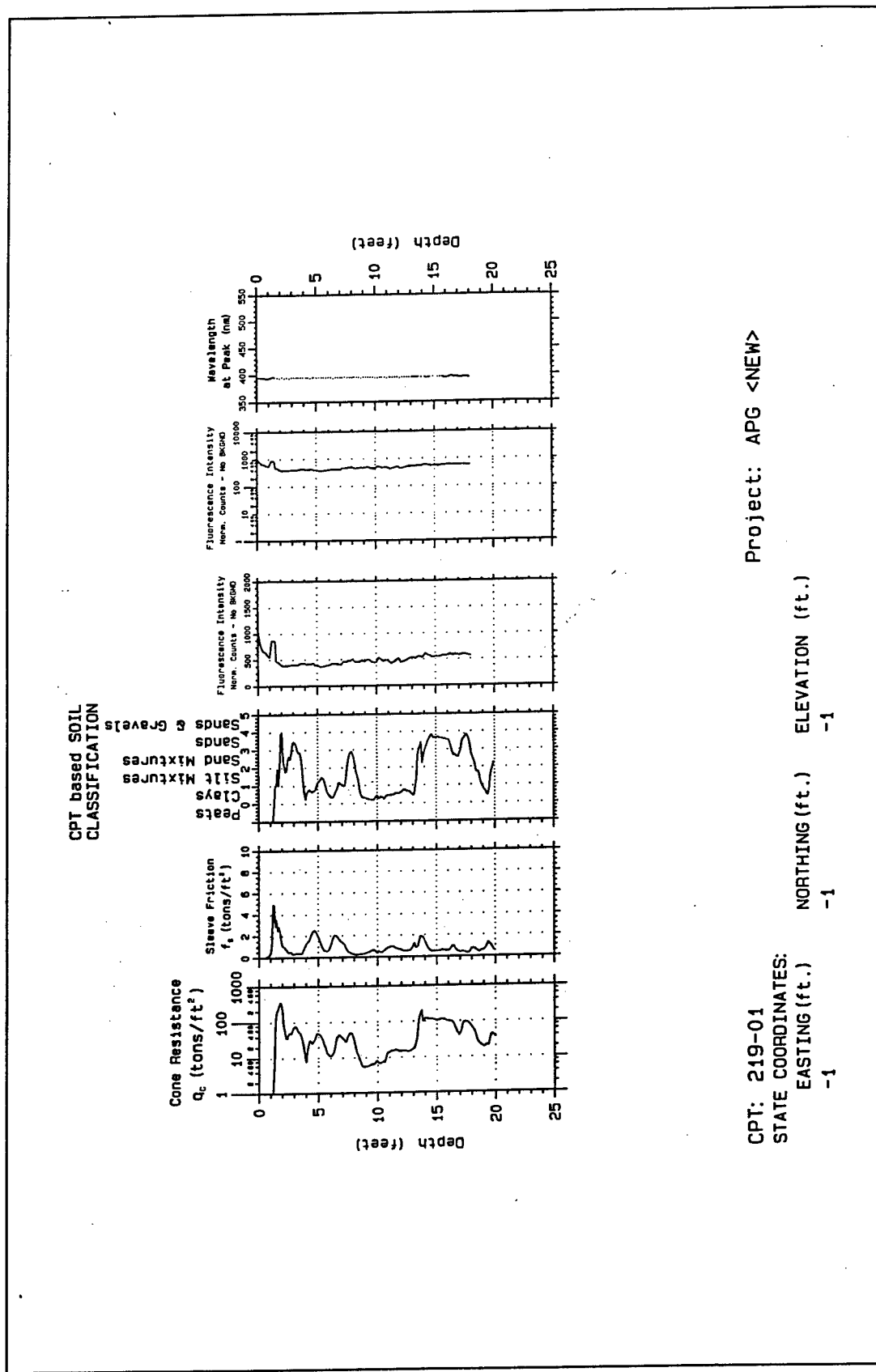


Figure A1. CPT 219-01, Aberdeen Proving Ground

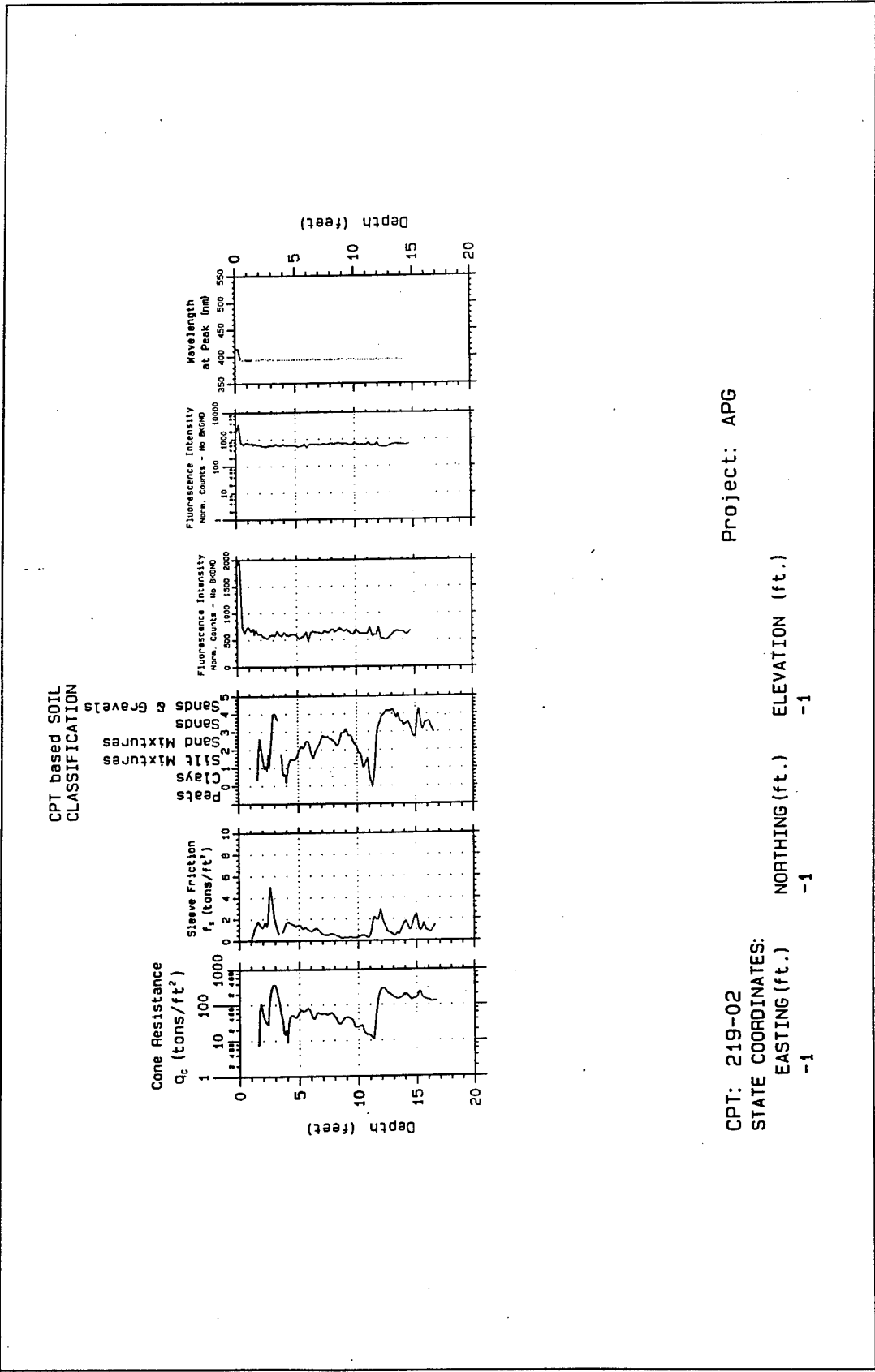


Figure A2. CPT 219-02, Aberdeen Proving Ground

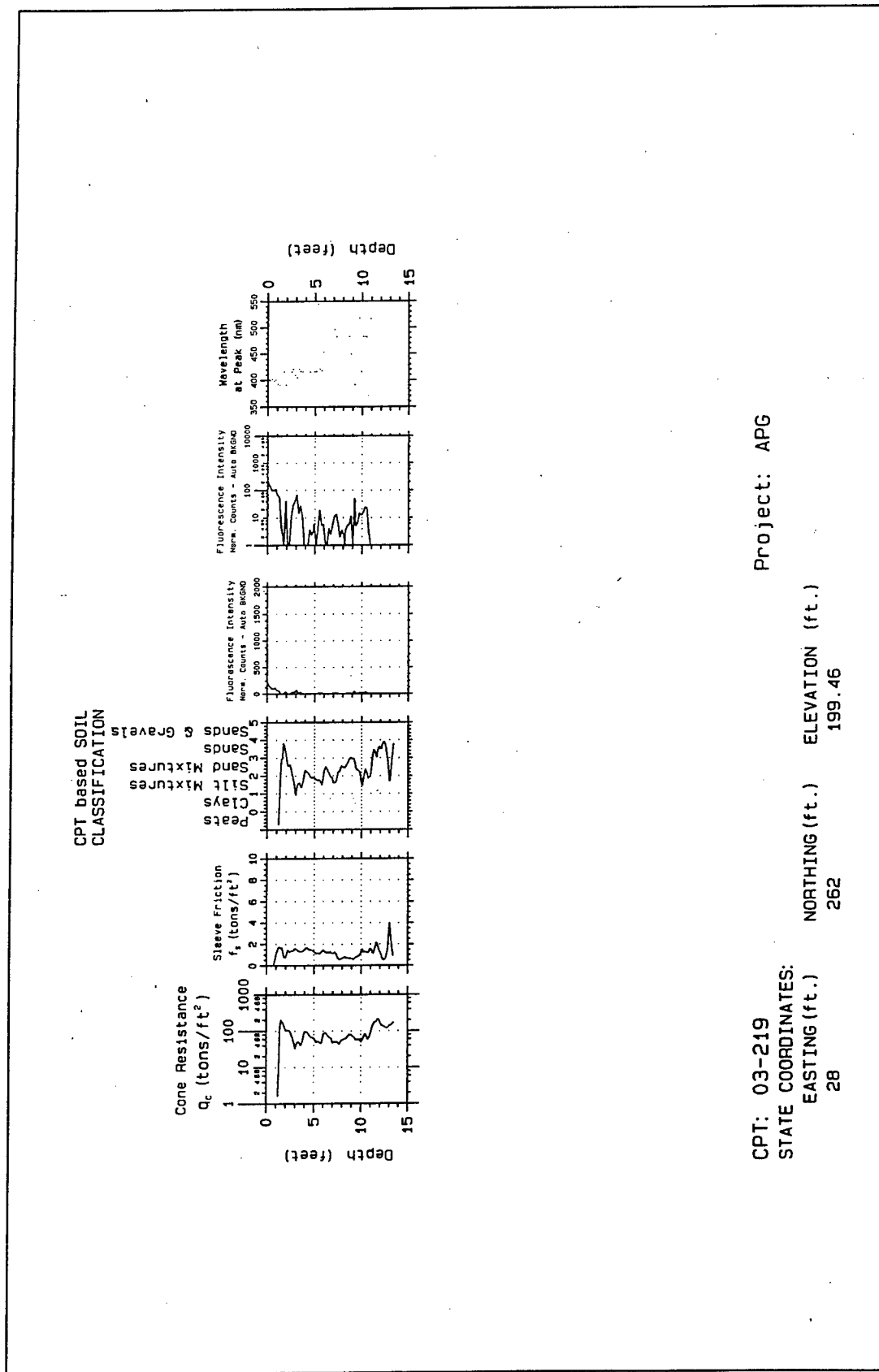


Figure A3. CPT 03-219, Aberdeen Proving Ground

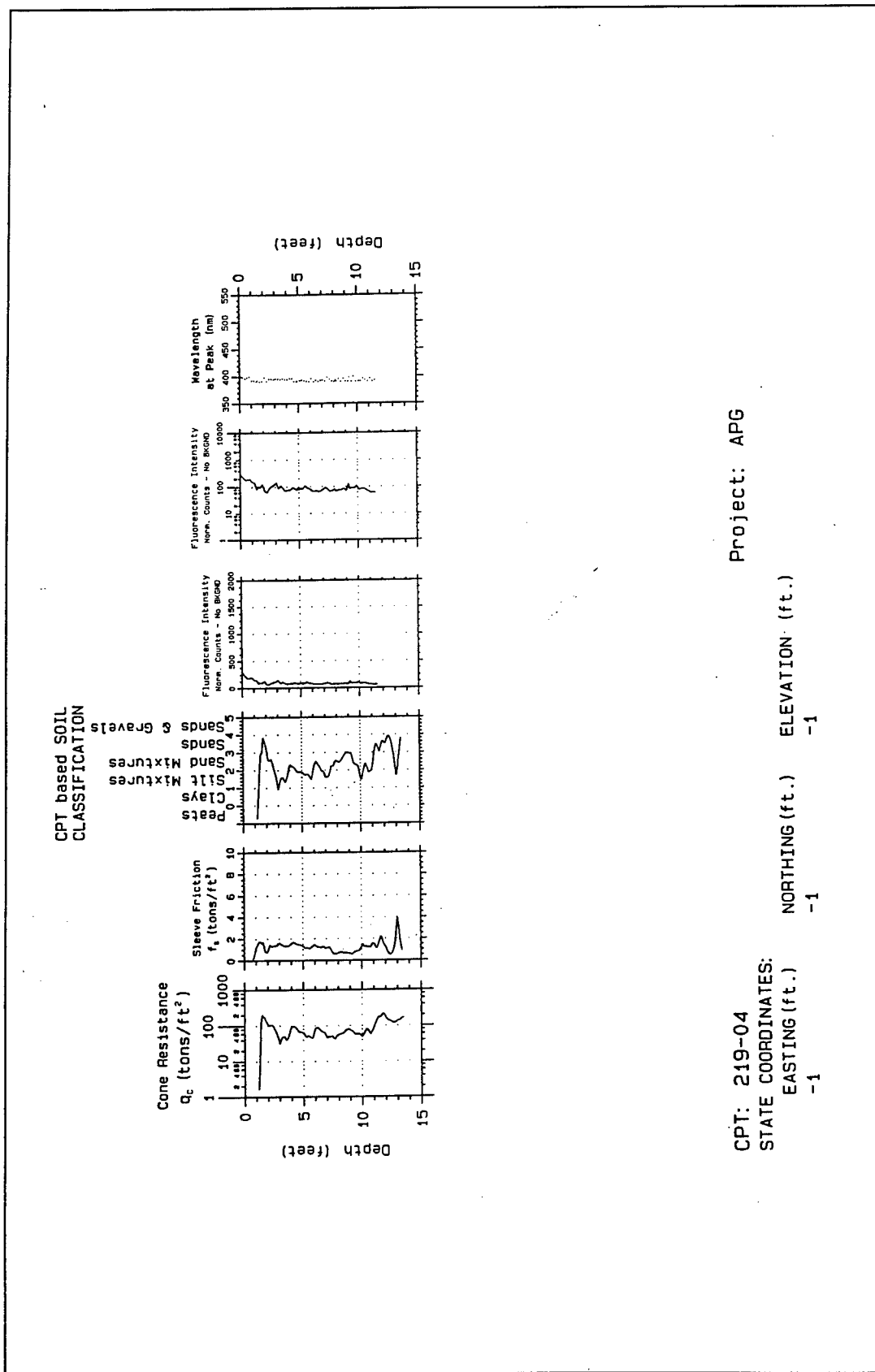


Figure A4. CPT 04-219, Aberdeen Proving Ground

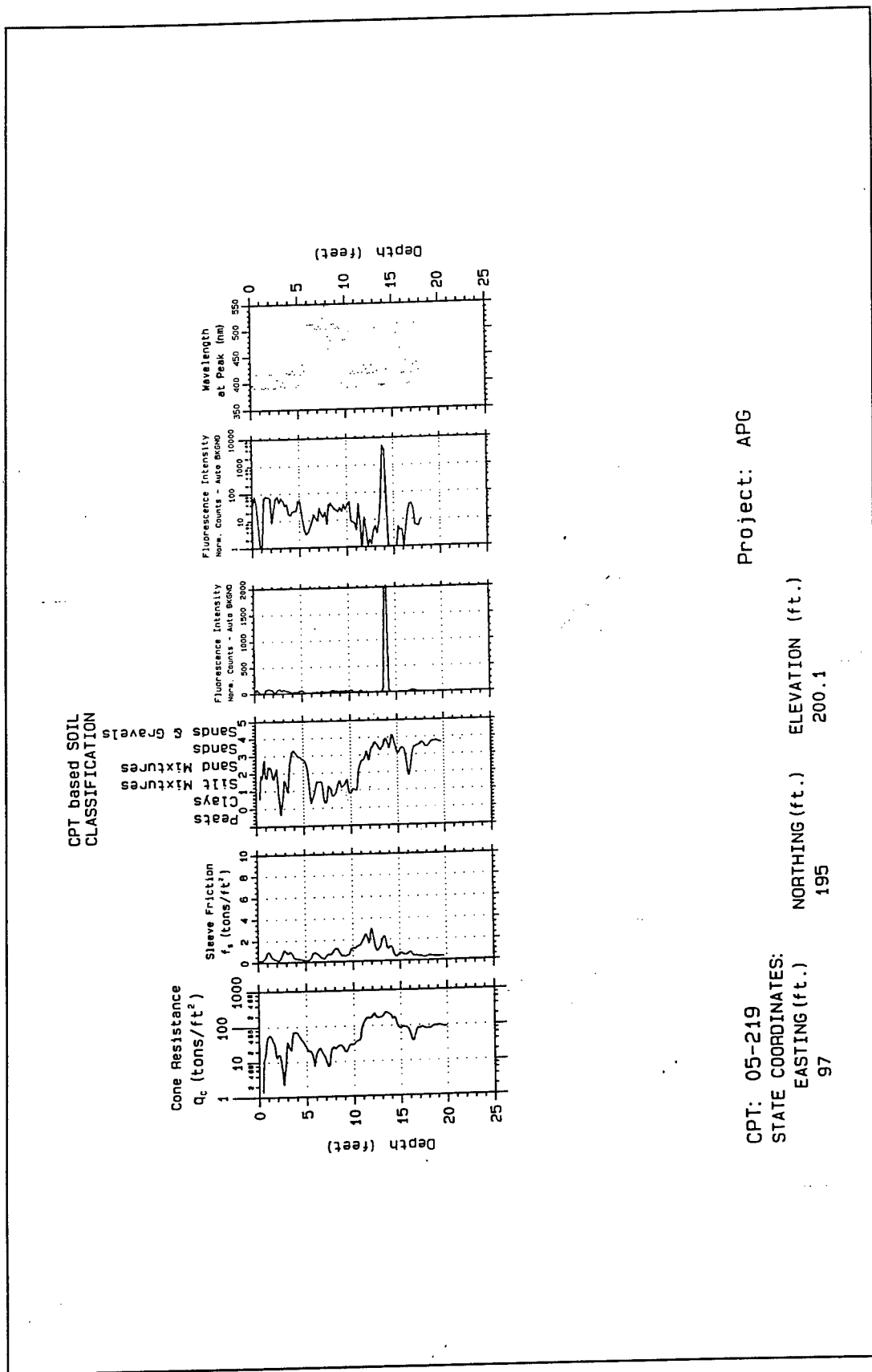


Figure A5. CPT 05-219, Aberdeen Proving Ground

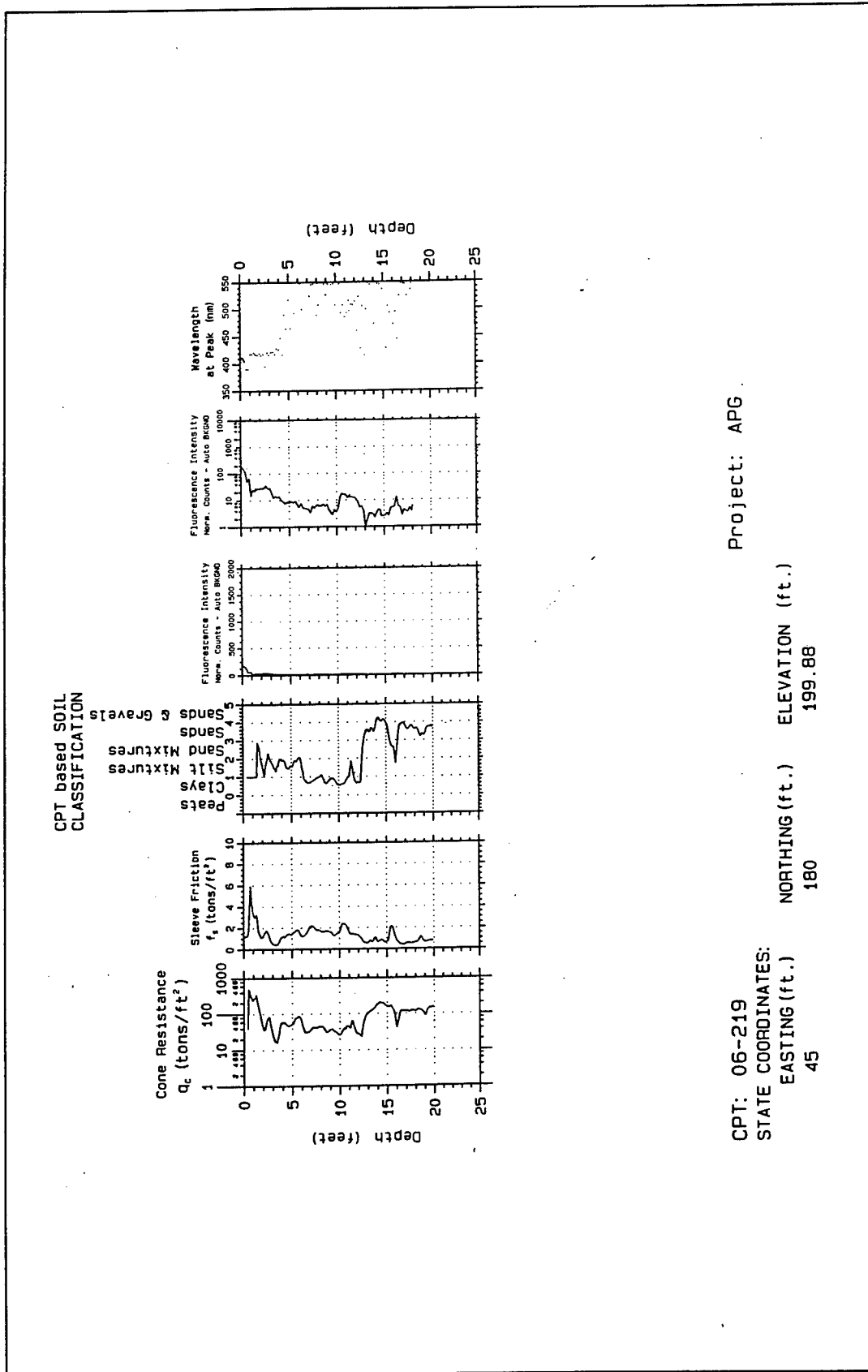


Figure A6. CPT 06-219, Aberdeen Proving Ground

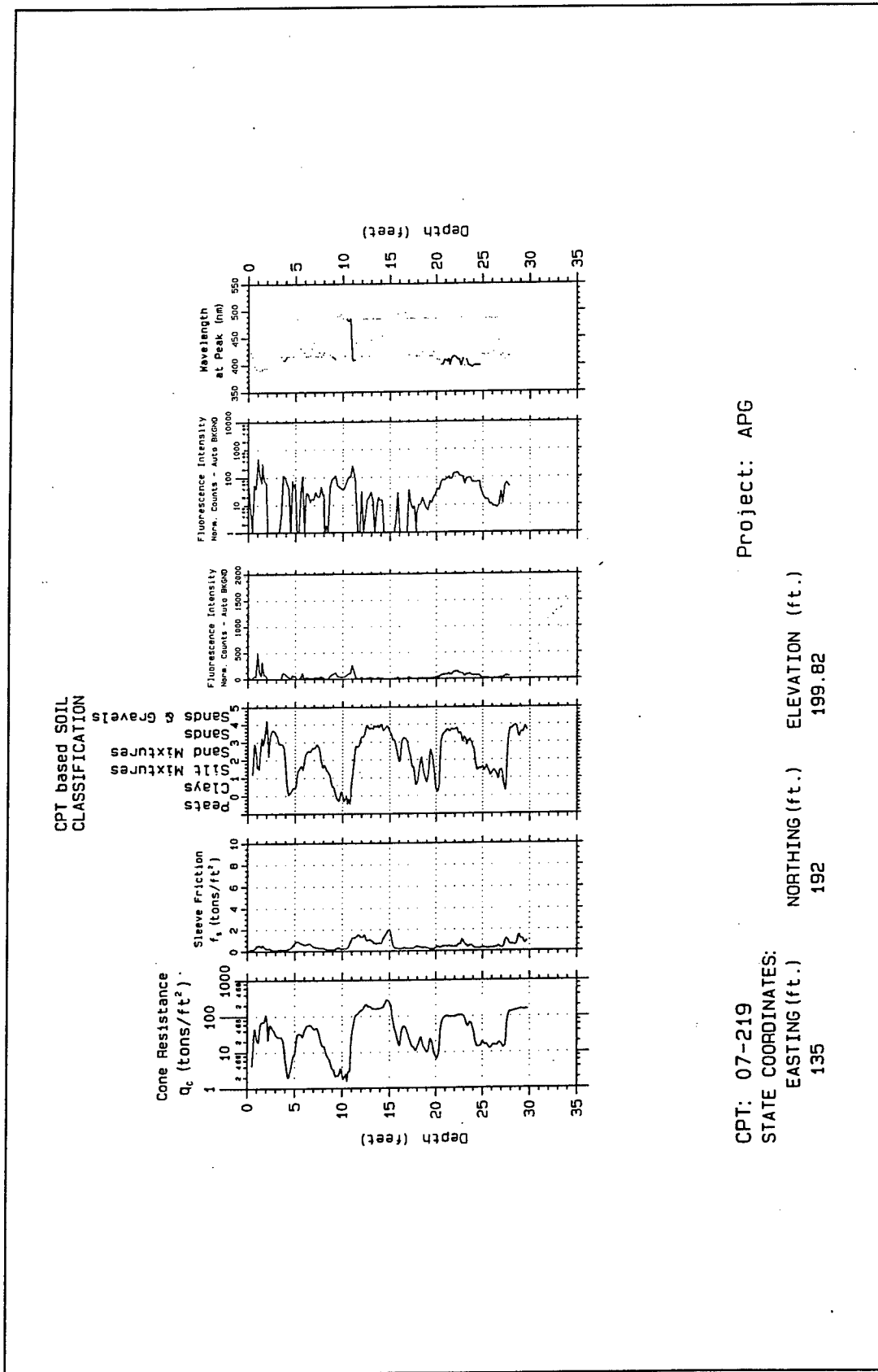


Figure A7. CPT 07-219, Aberdeen Proving Ground



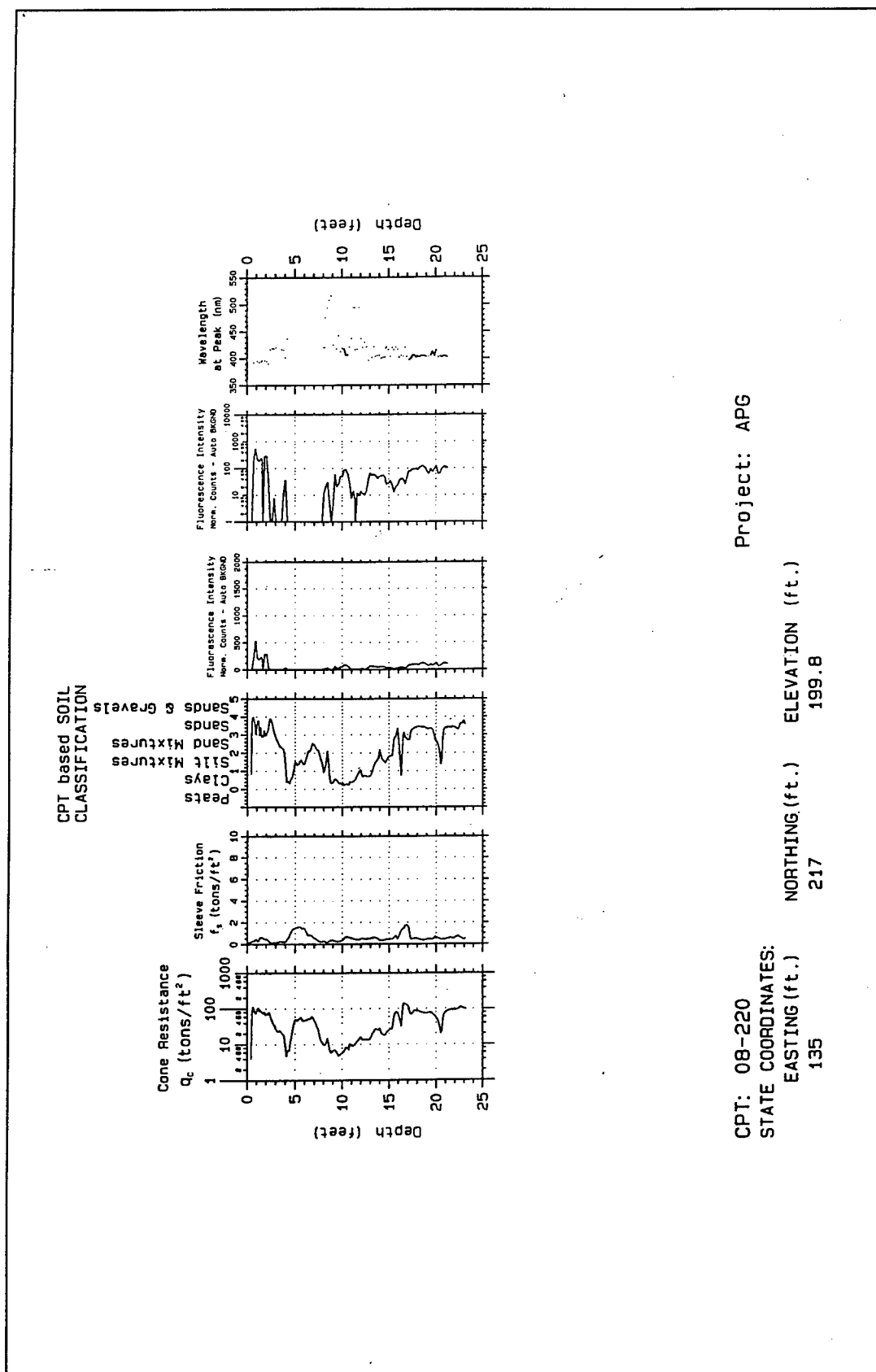


Figure A8. CPT 08-220, Aberdeen Proving Ground

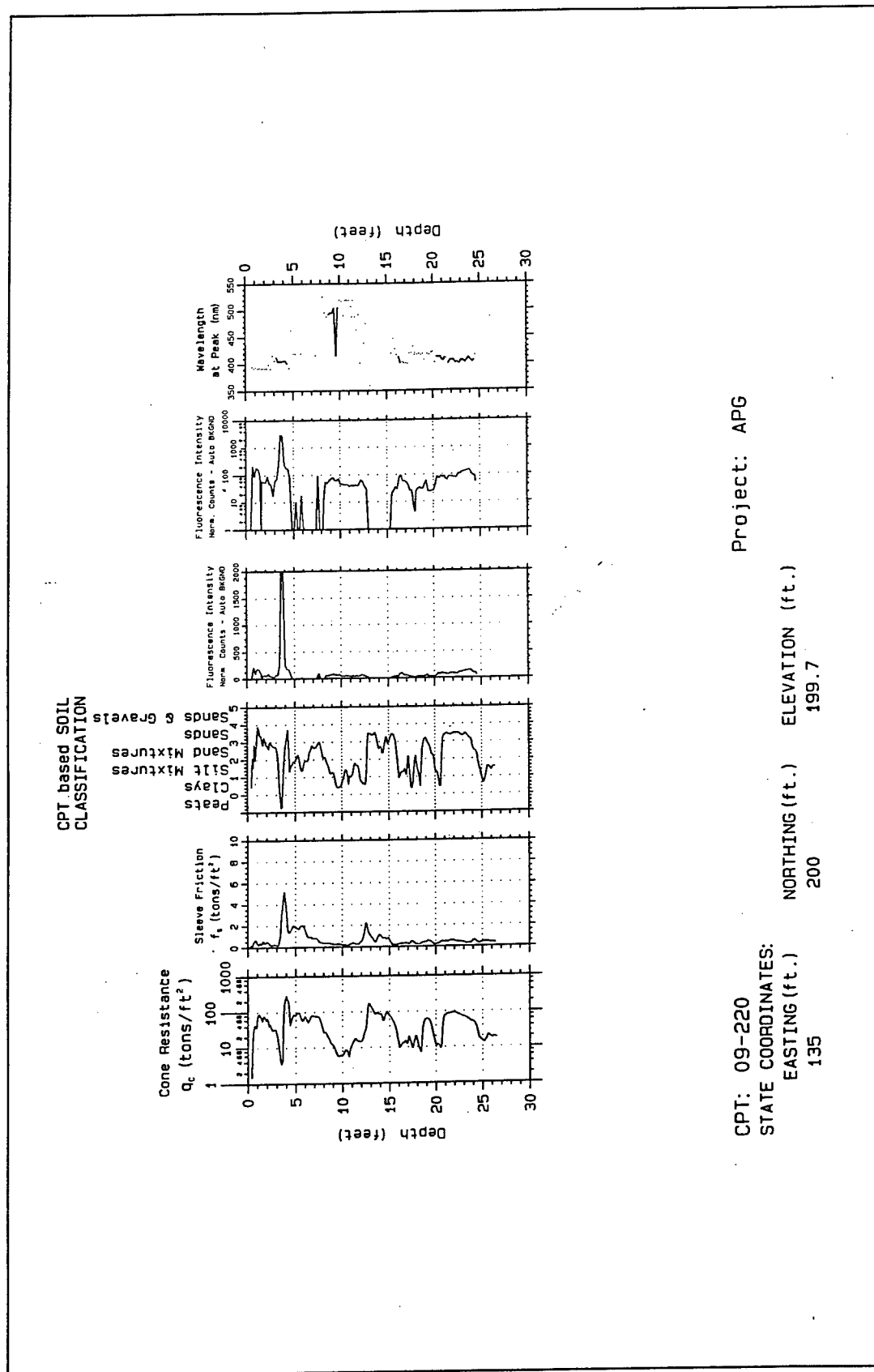


Figure A9. CPT 09-220, Aberdeen Proving Ground

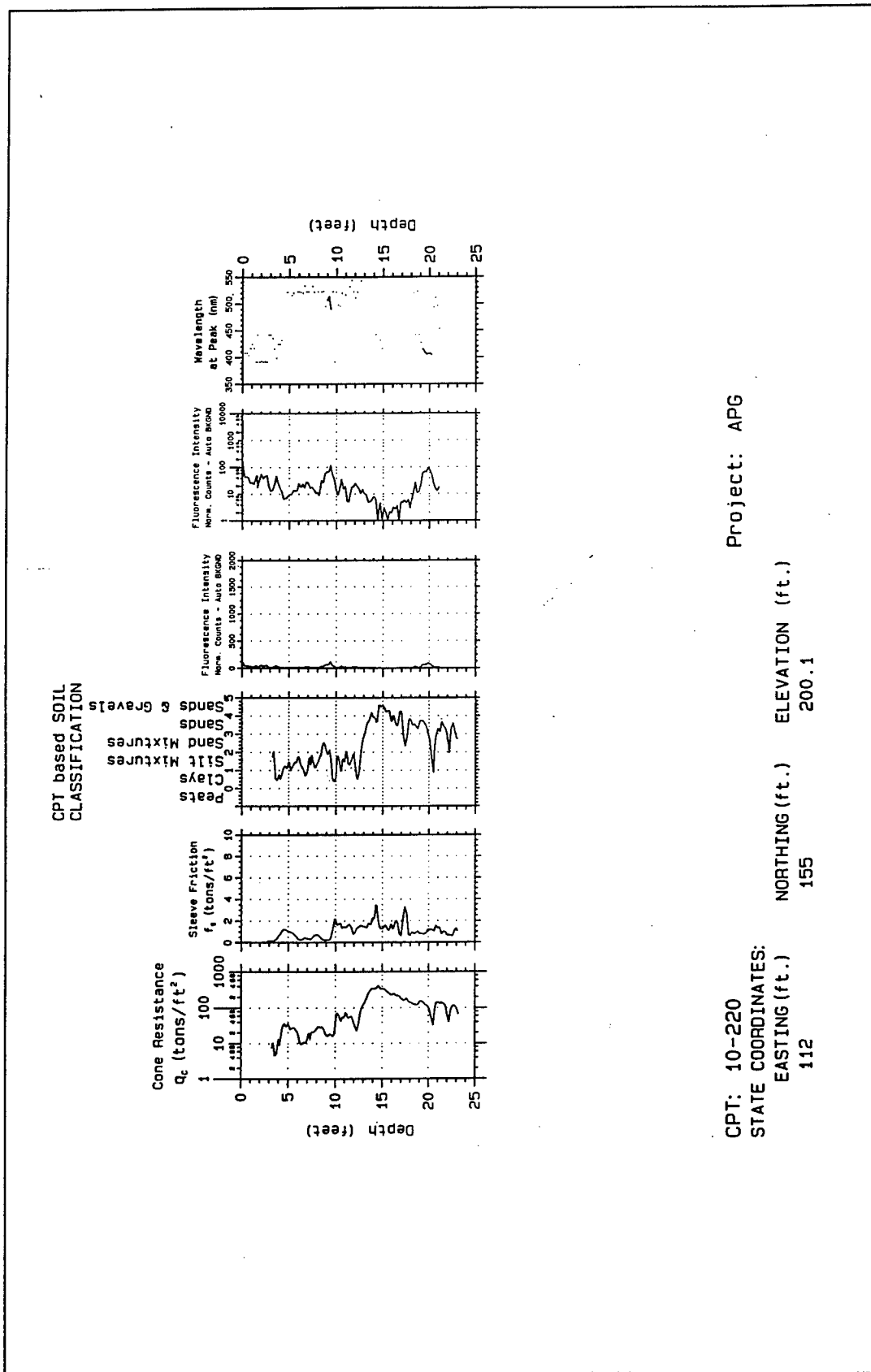


Figure A10. CPT 10-220, Aberdeen Proving Ground

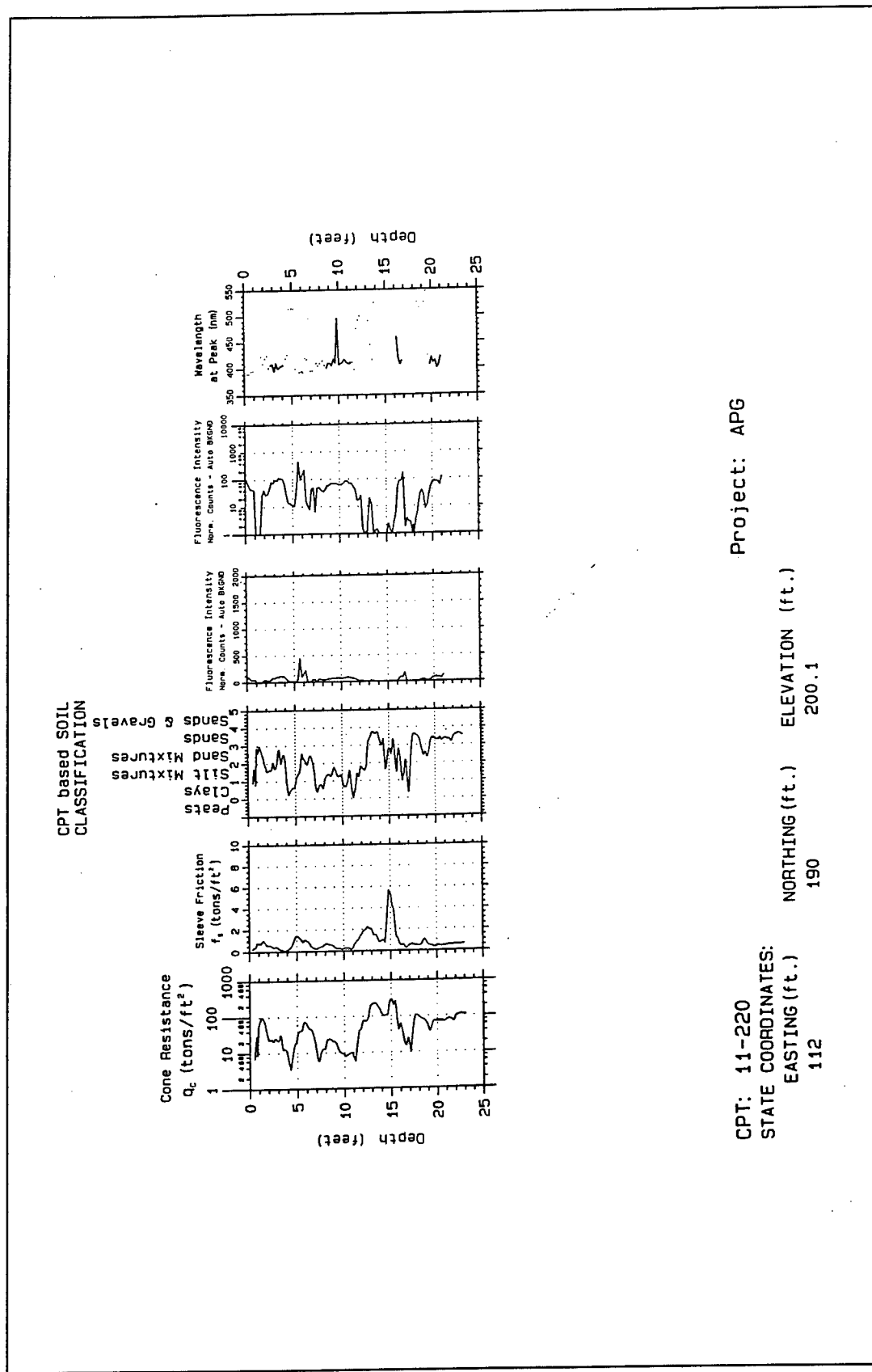


Figure A11. CPT 11-220, Aberdeen Proving Ground

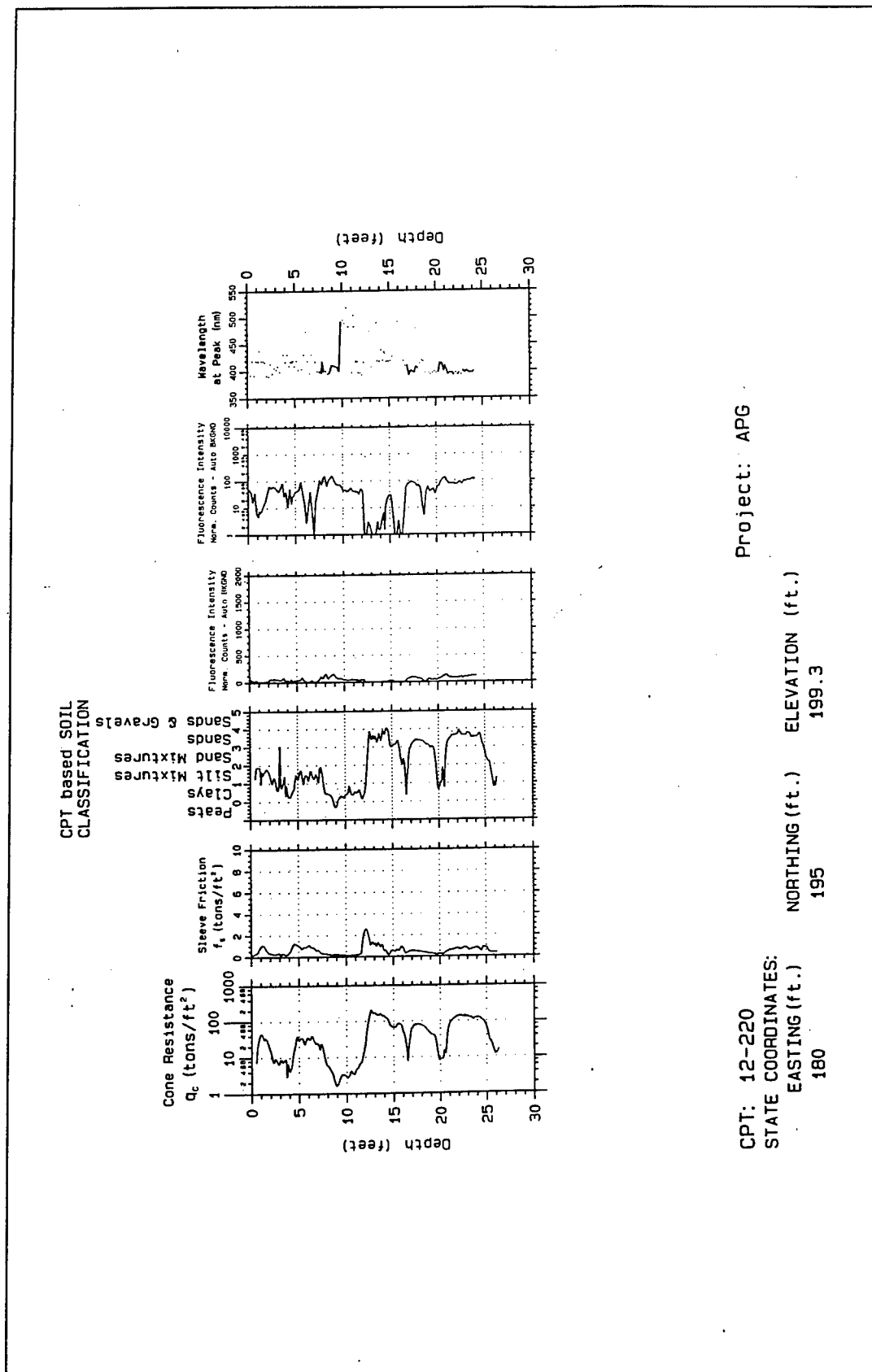


Figure A12. CPT 12-220, Aberdeen Proving Ground

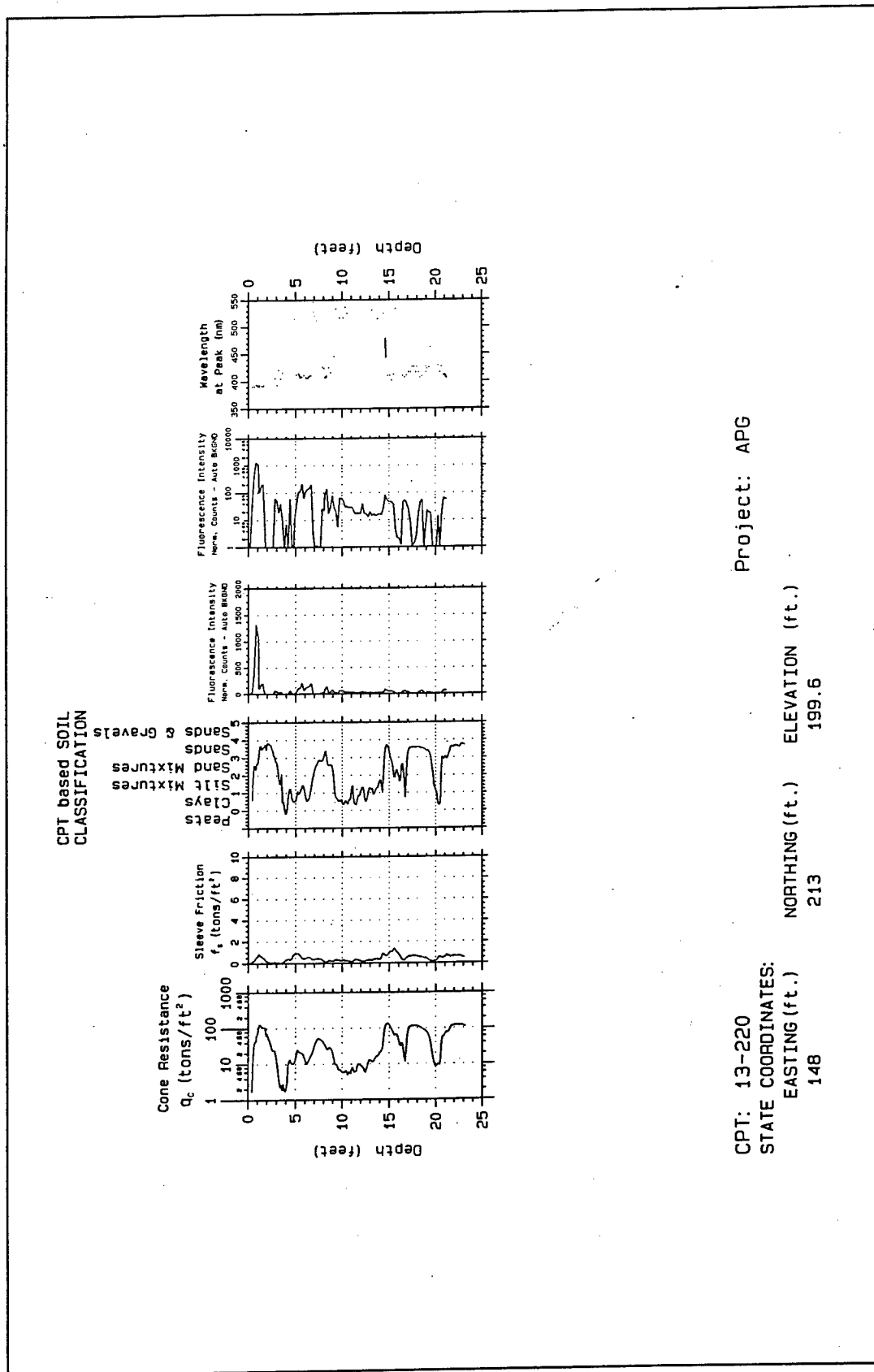


Figure A13. CPT 13-220, Aberdeen Proving Ground

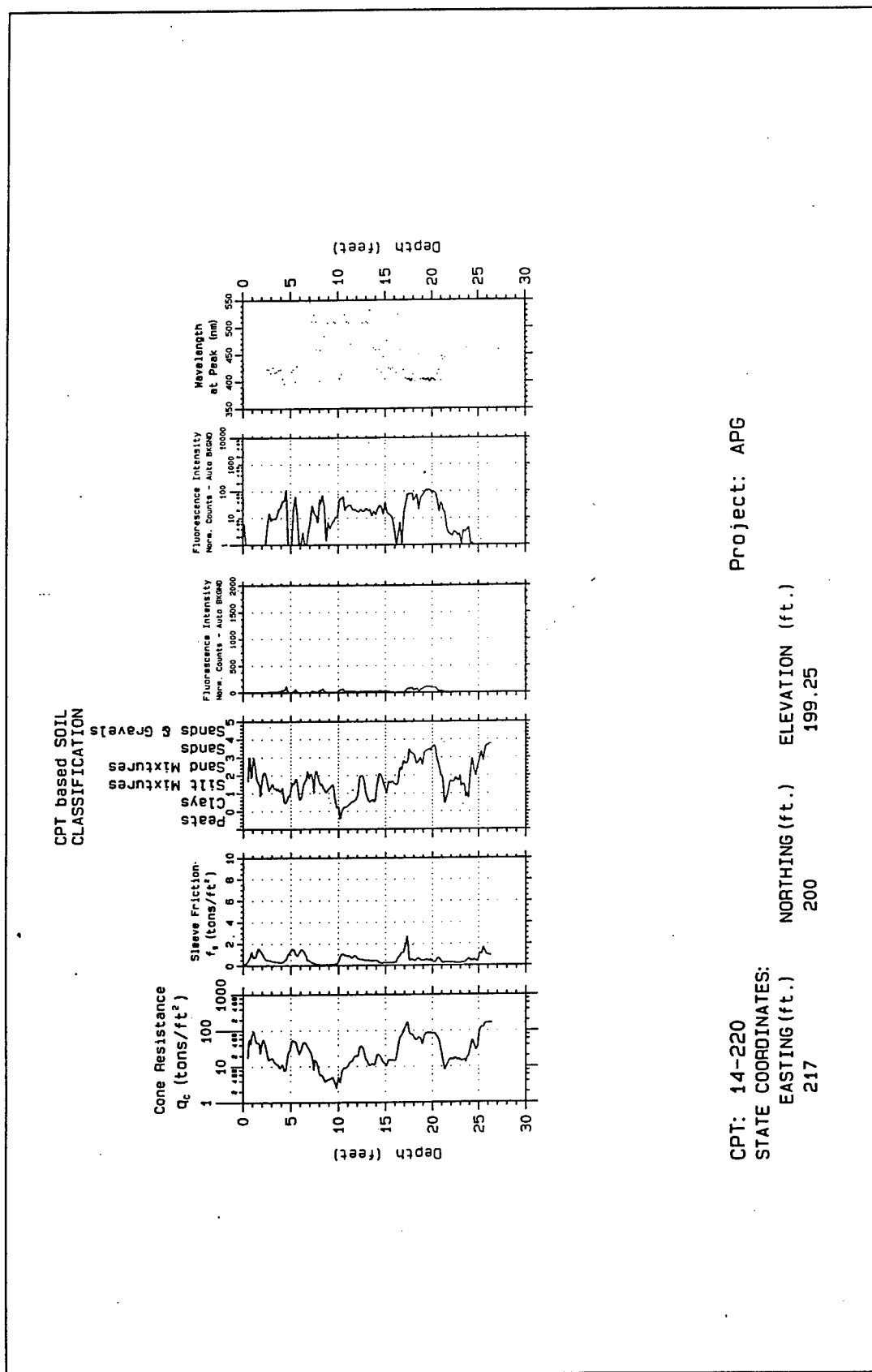


Figure A14. CPT 14-220, Aberdeen Proving Ground

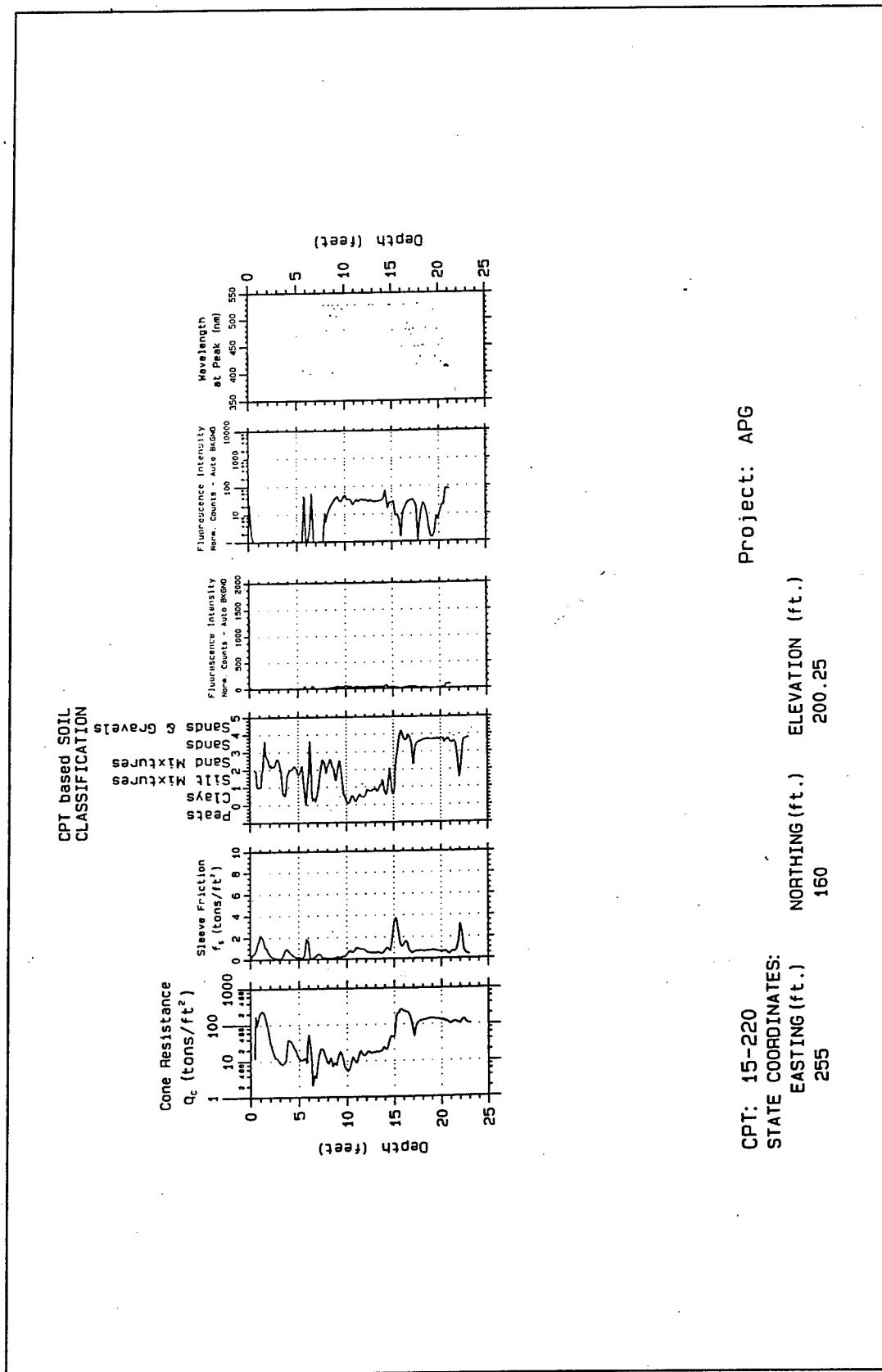


Figure A15. CPT 15-220, Aberdeen Proving Ground



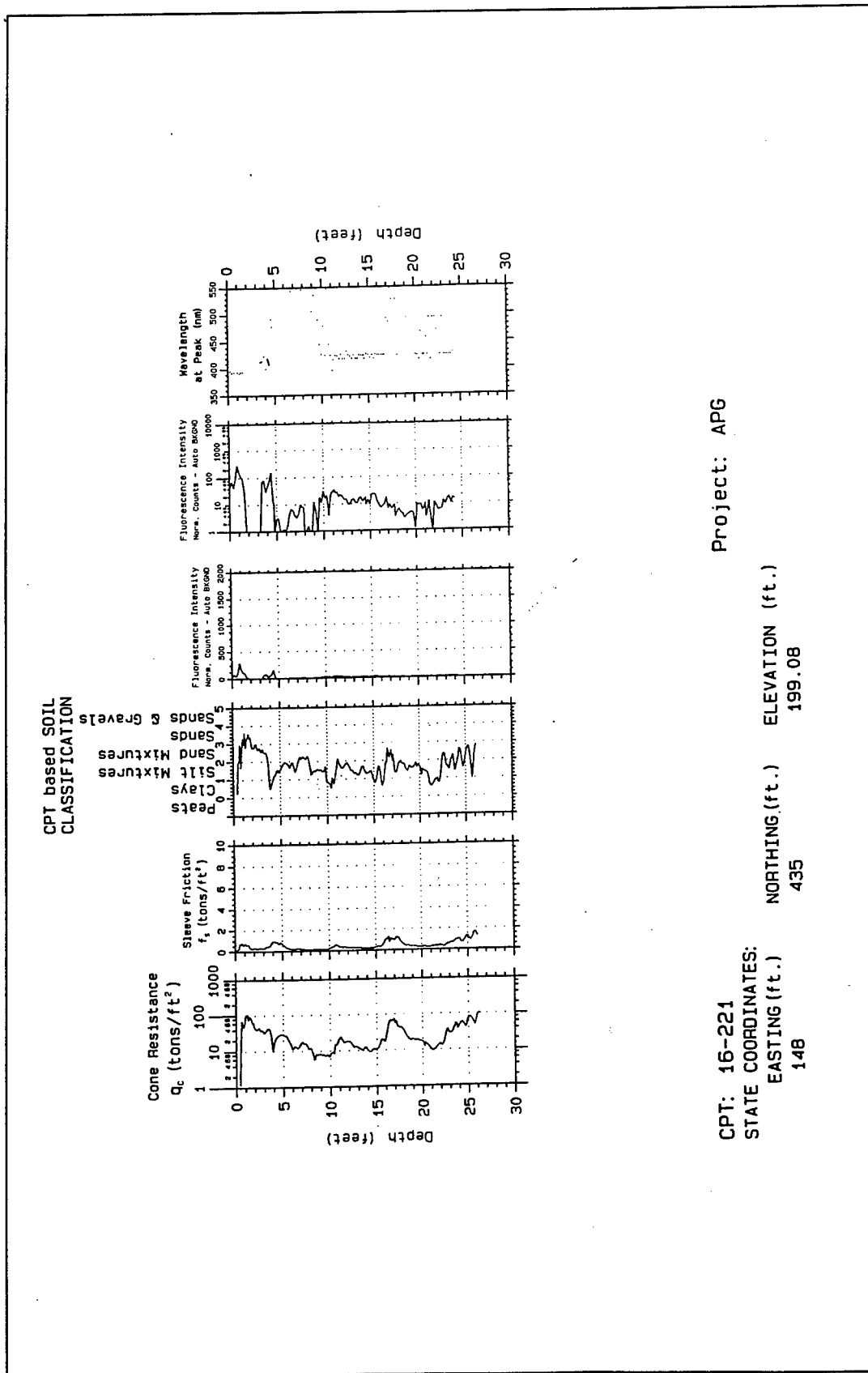


Figure A16. CPT 16-221, Aberdeen Proving Ground

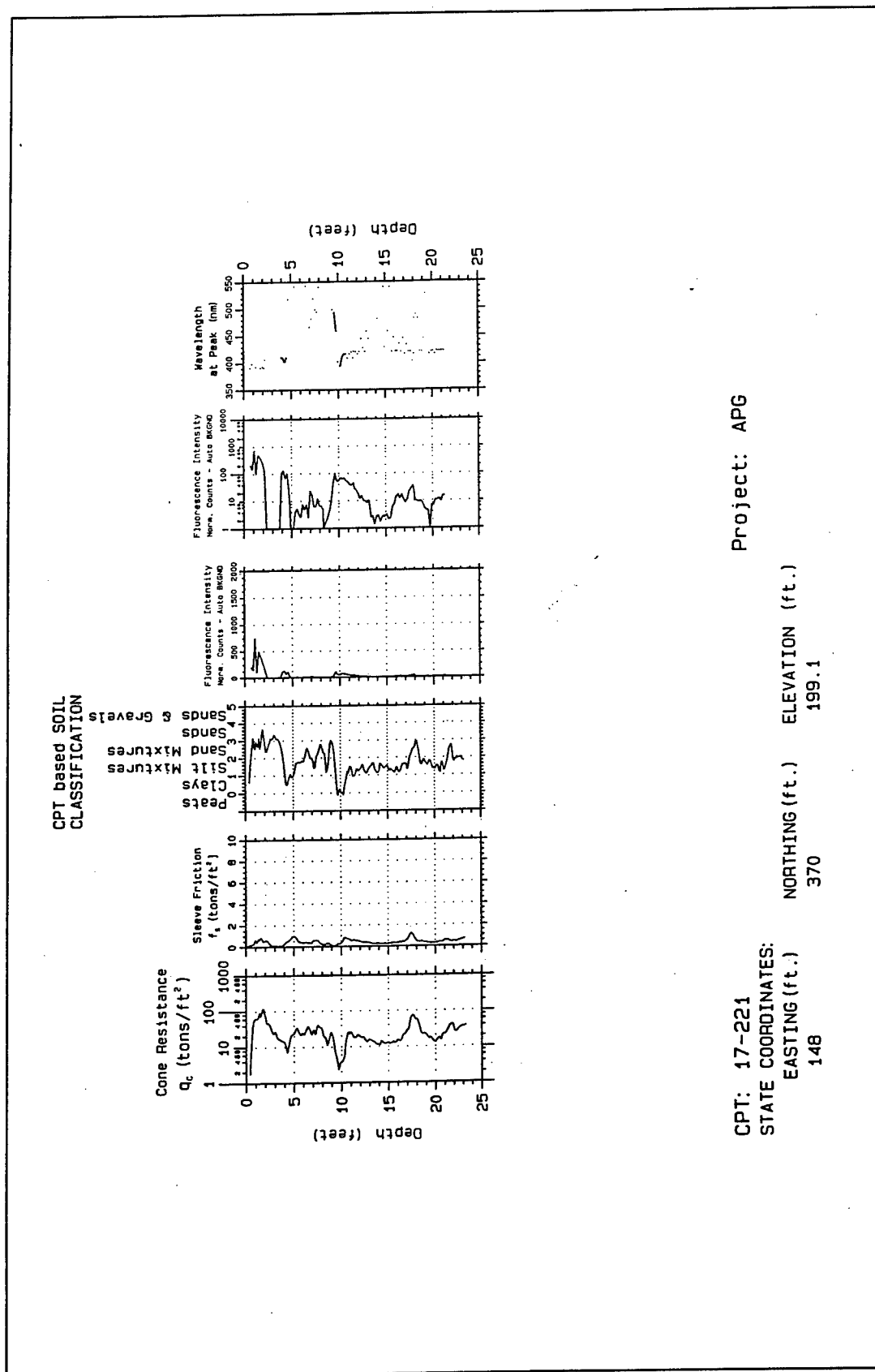


Figure A17. CPT 17-221, Aberdeen Proving Ground

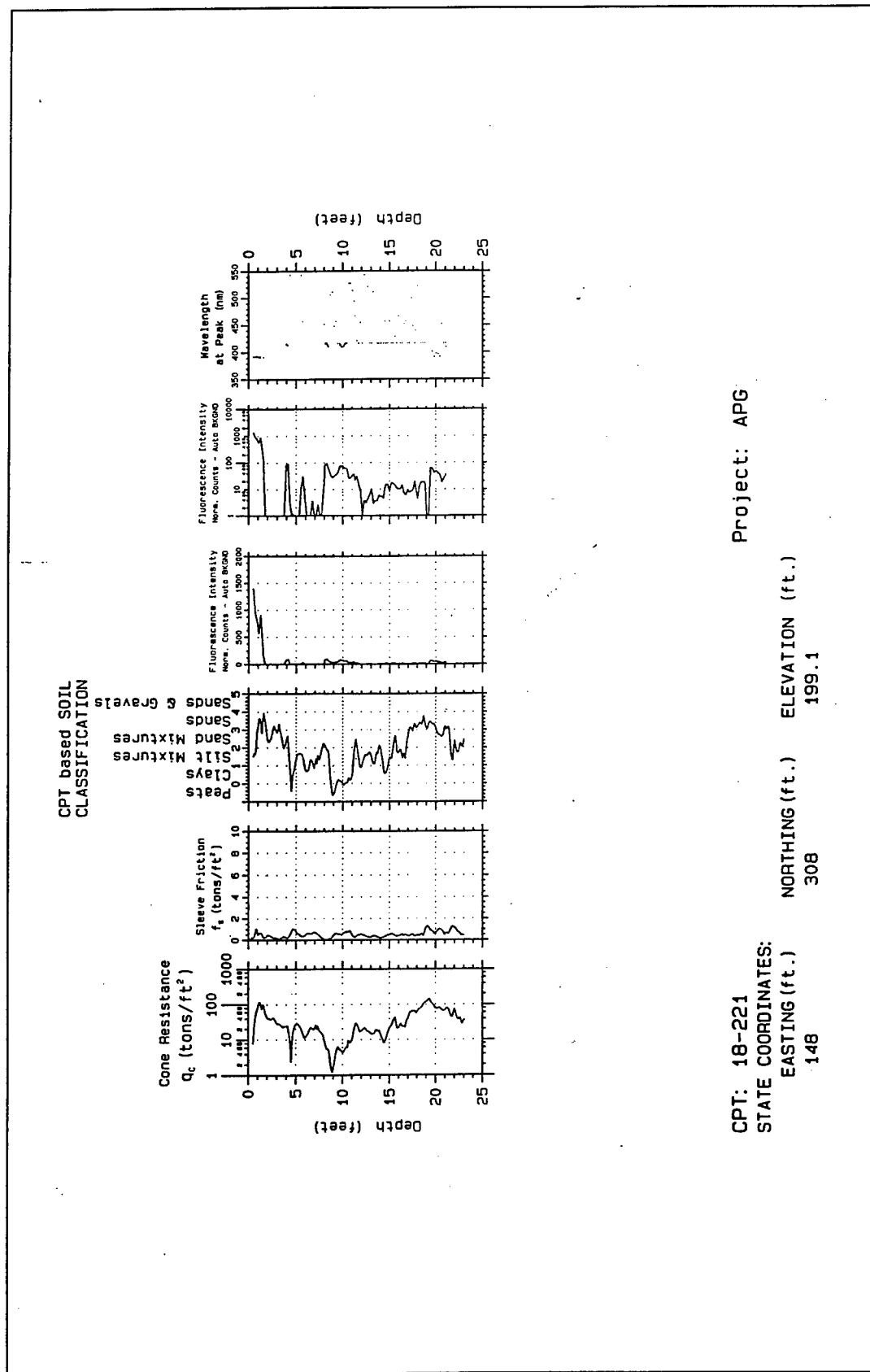


Figure A18. CPT 18-221, Aberdeen Proving Ground

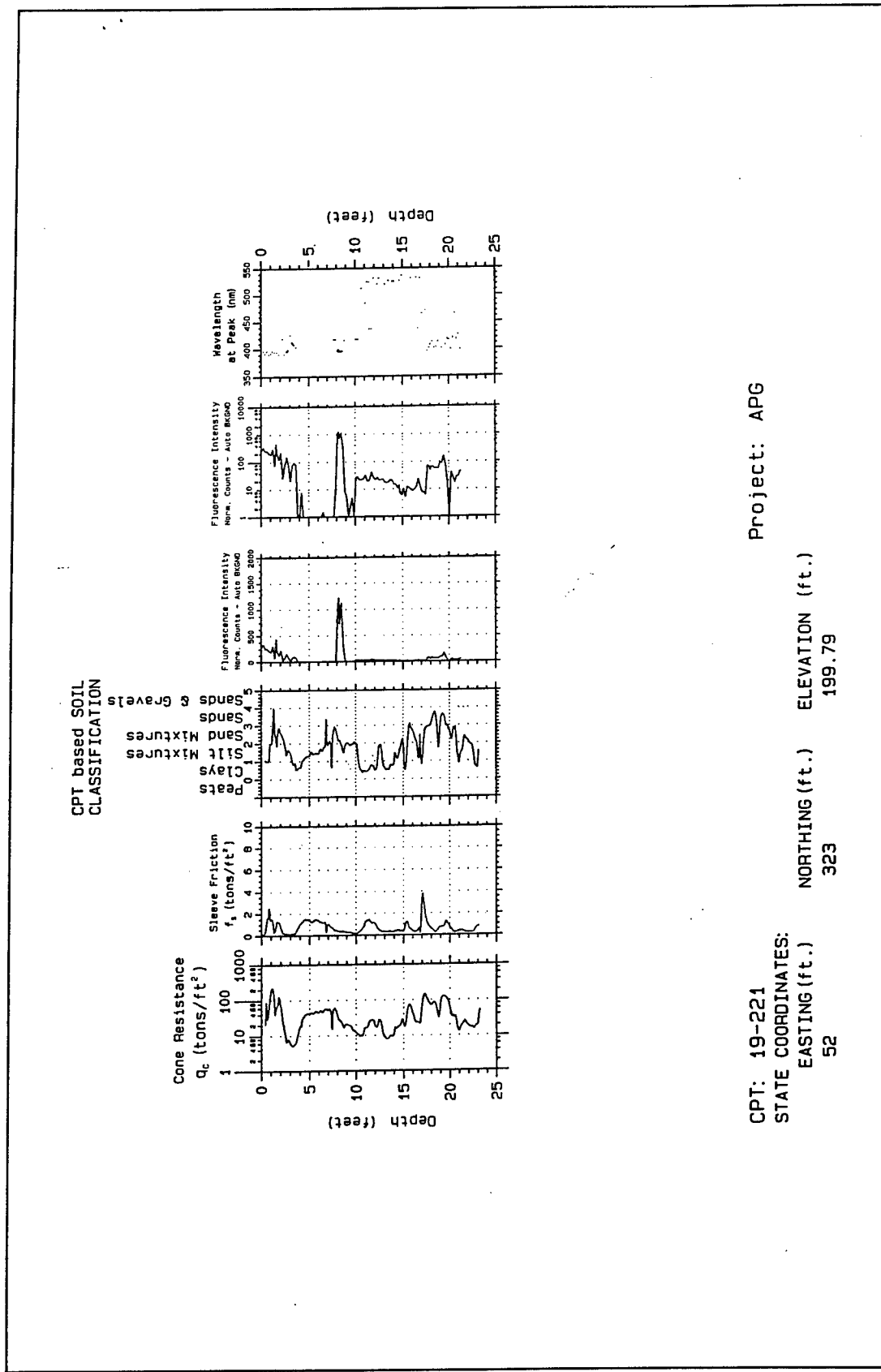


Figure A19. CPT 19-221, Aberdeen Proving Ground

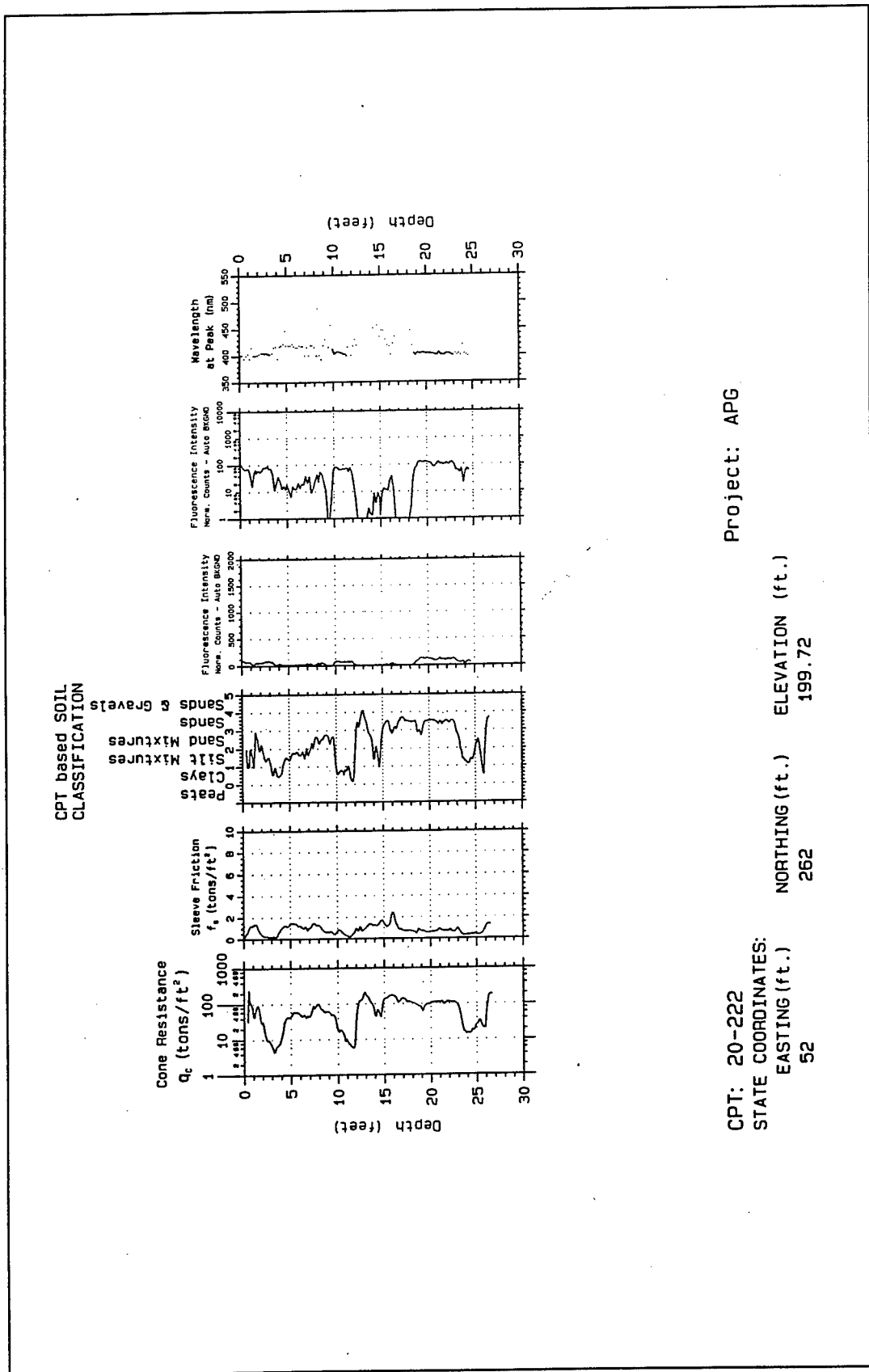


Figure A20. CPT 20-222, Aberdeen Proving Ground

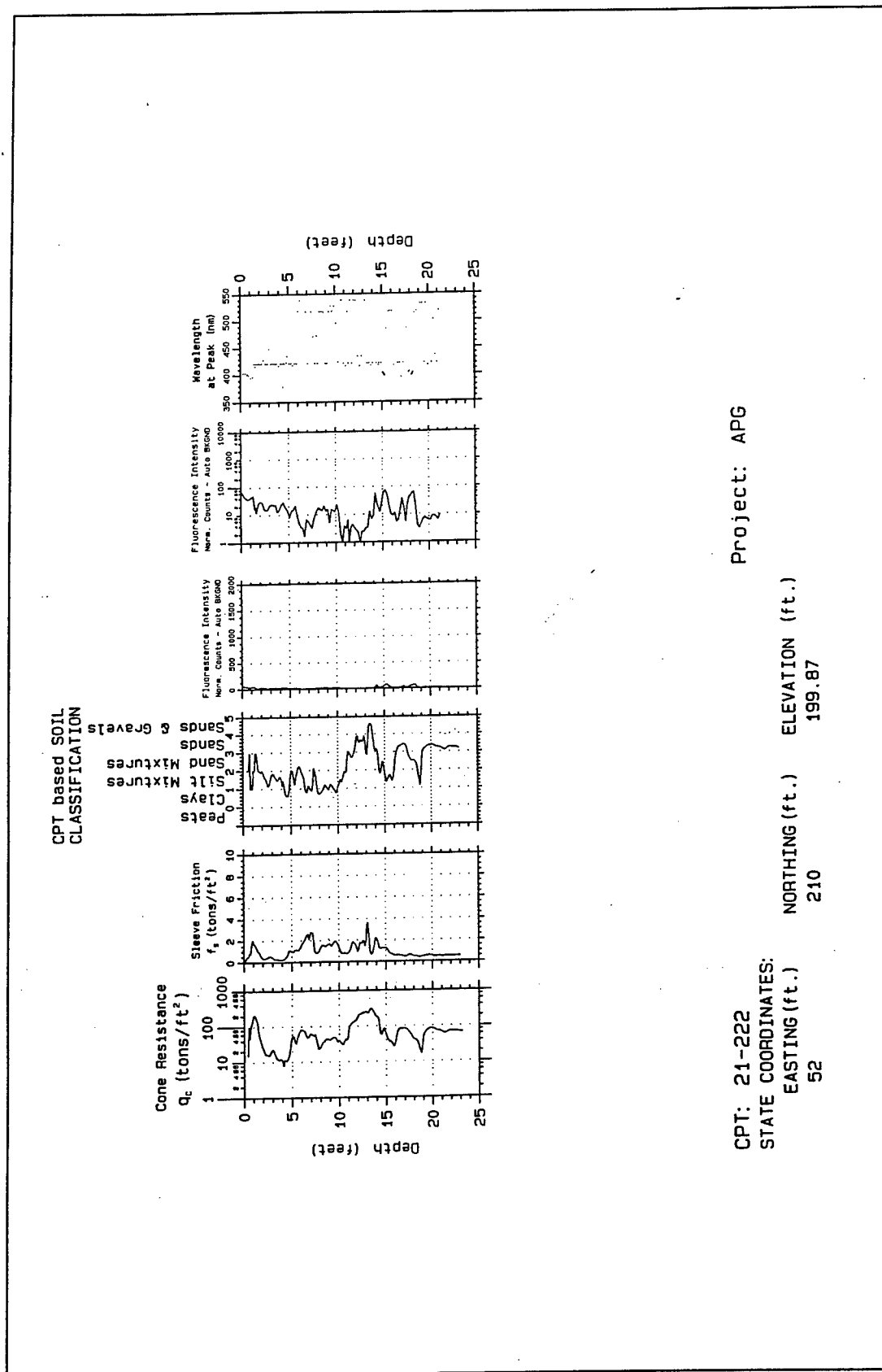


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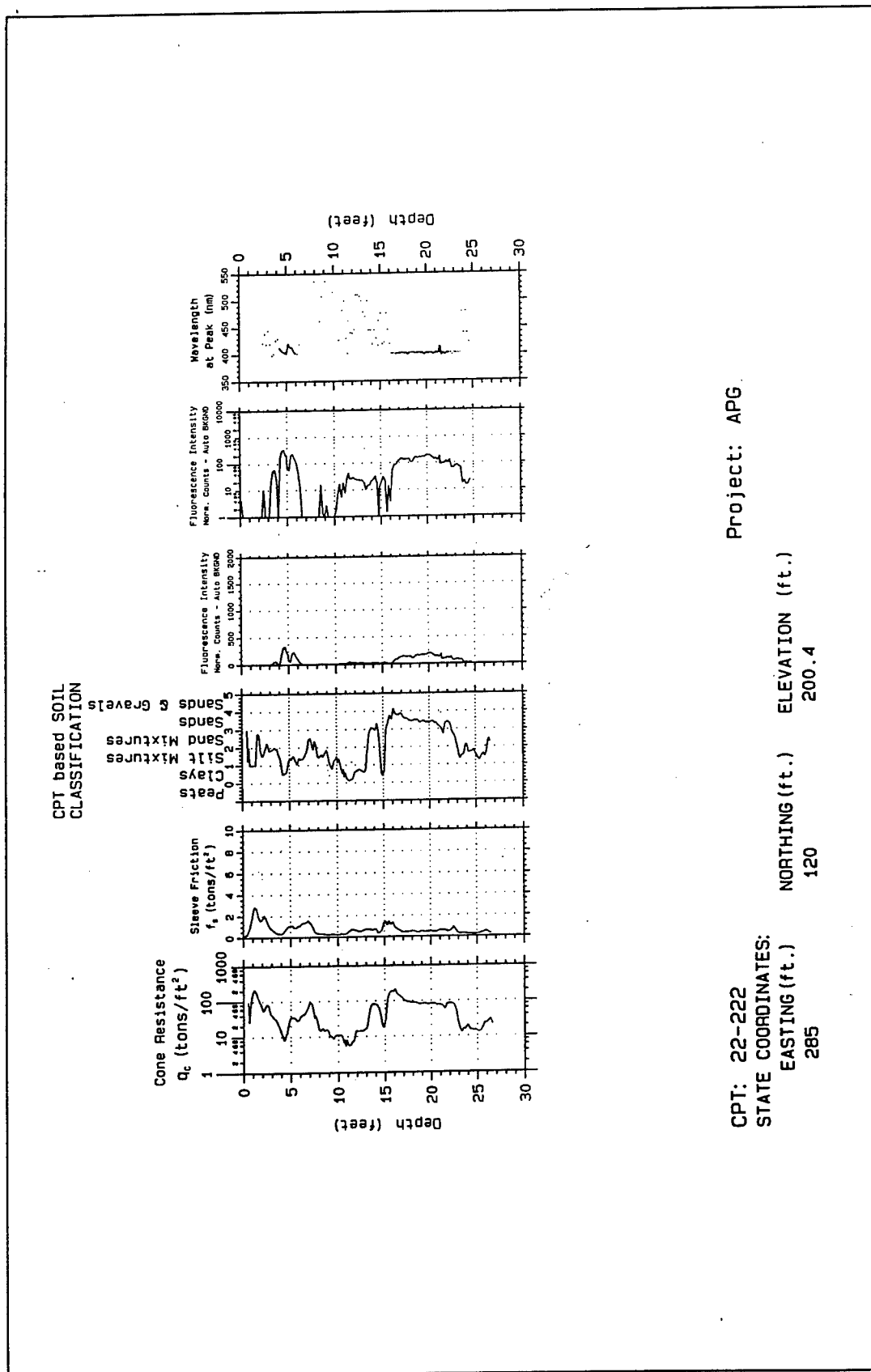


Figure A22. CPT 22-222, Aberdeen Proving Ground

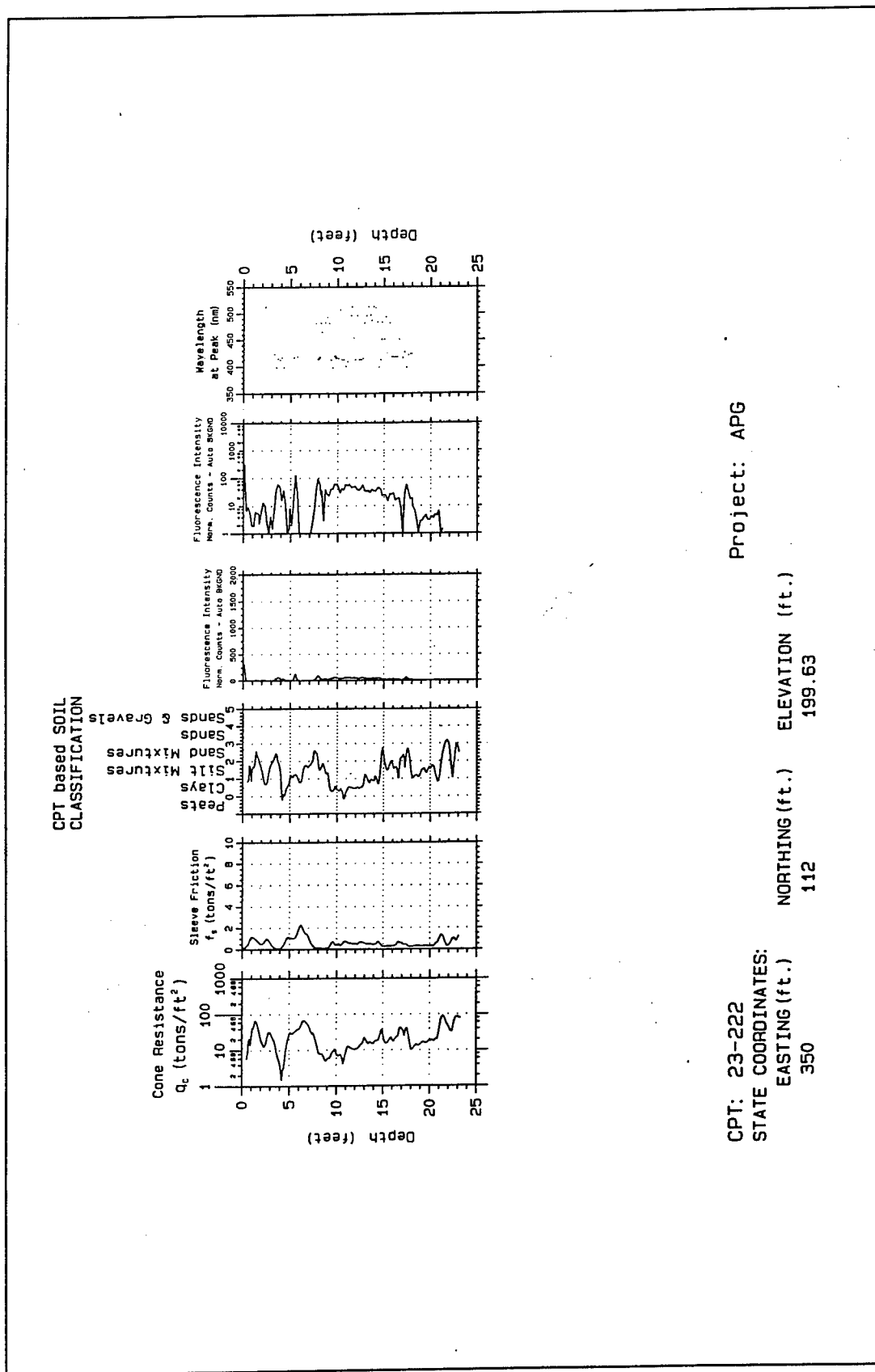


Figure A23. CPT 23-222, Aberdeen Proving Ground



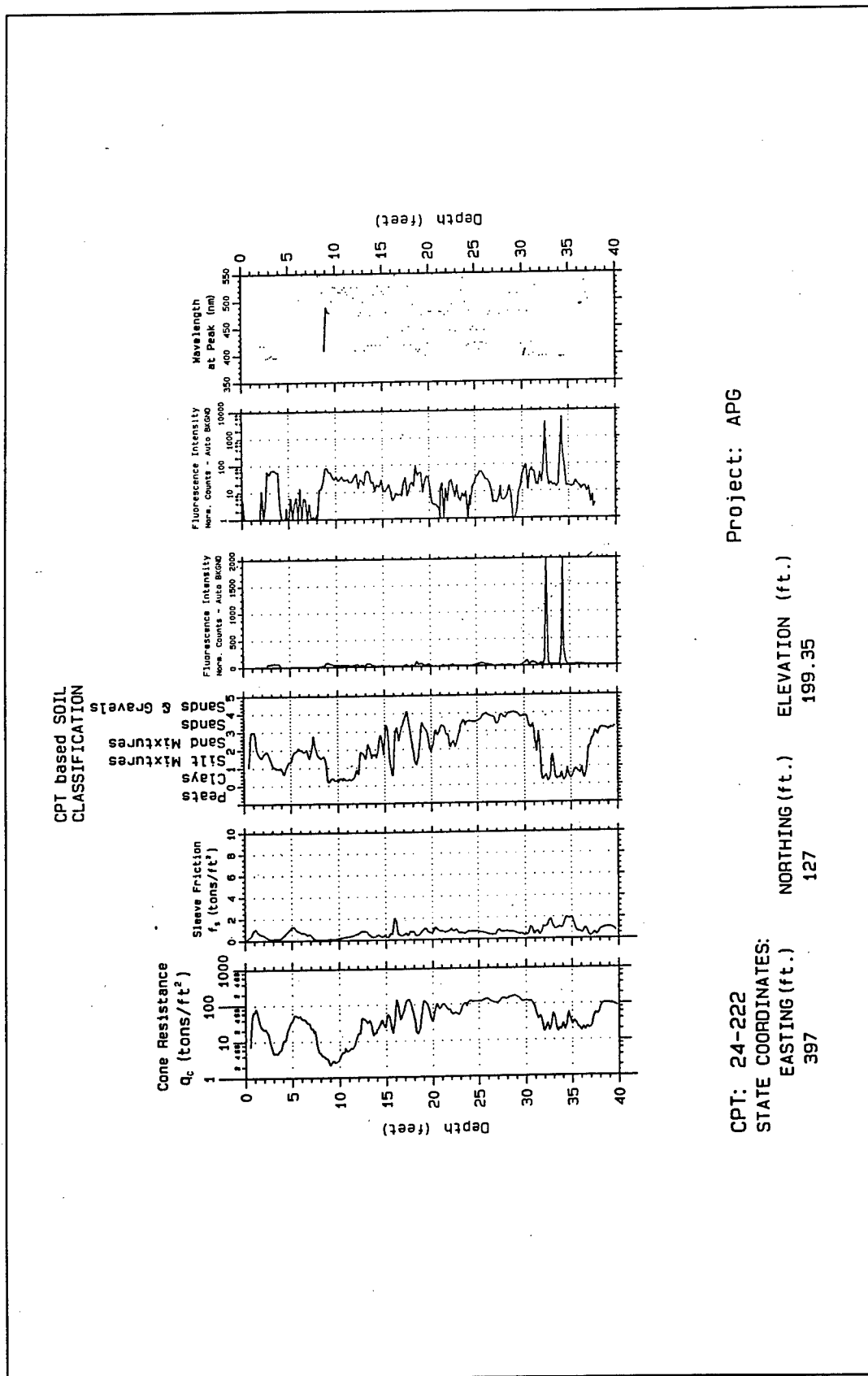


Figure A24. CPT 24-222, Aberdeen Proving Ground

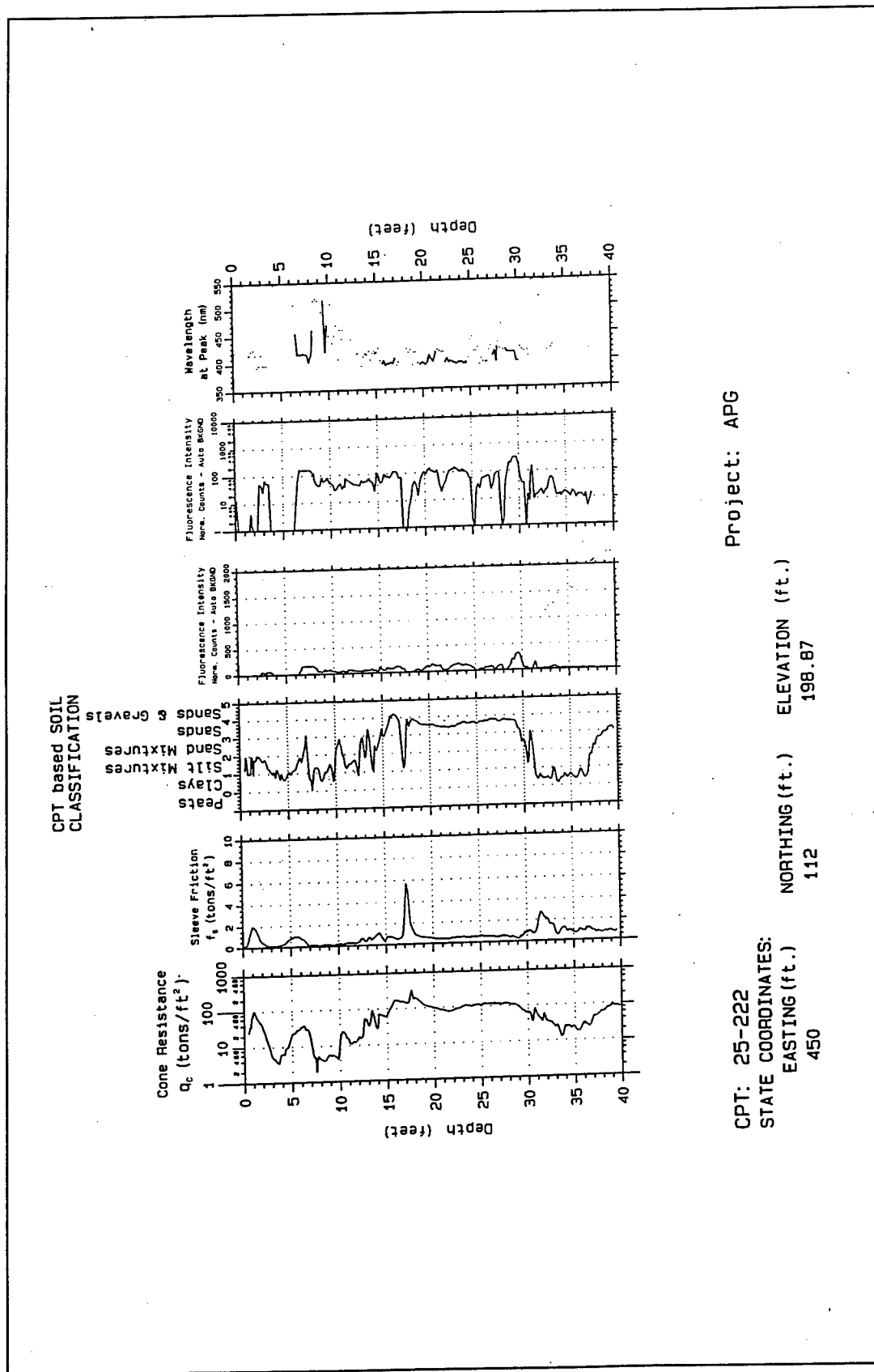


Figure A25. CPT 25-222, Aberdeen Proving Ground

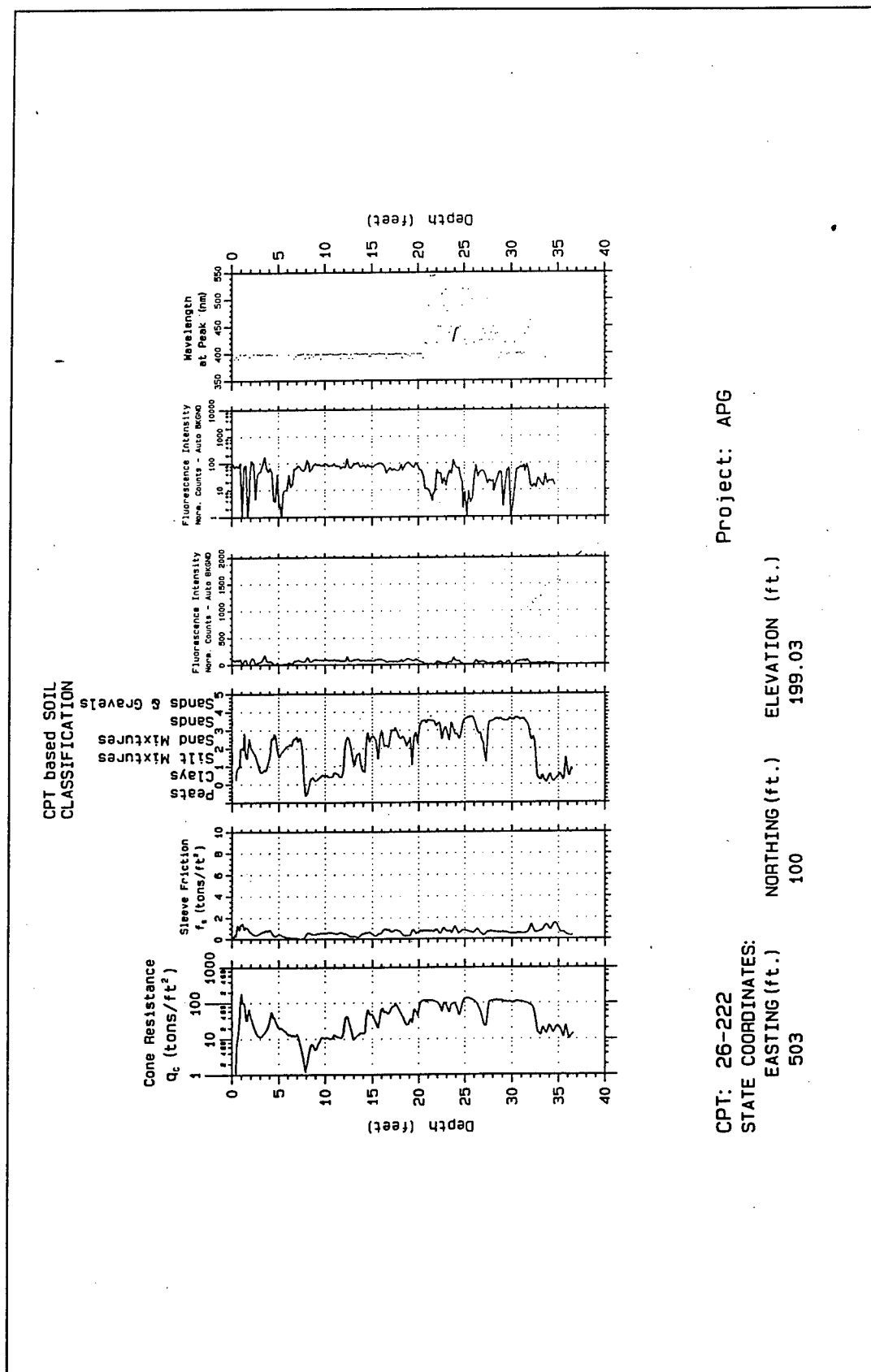


Figure A26. CPT 26-222, Aberdeen Proving Ground

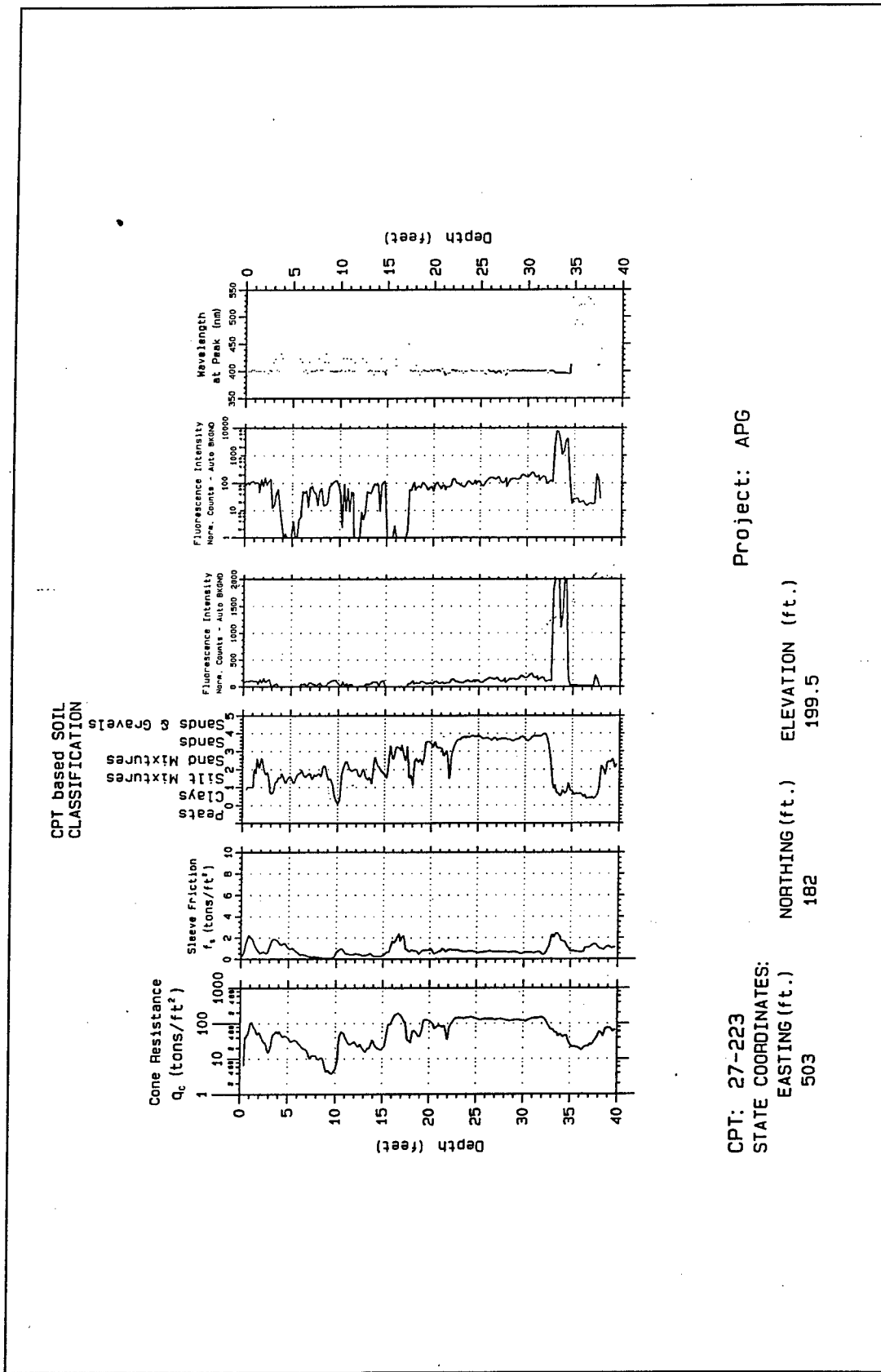


Figure A27. CPT 27-223, Aberdeen Proving Ground

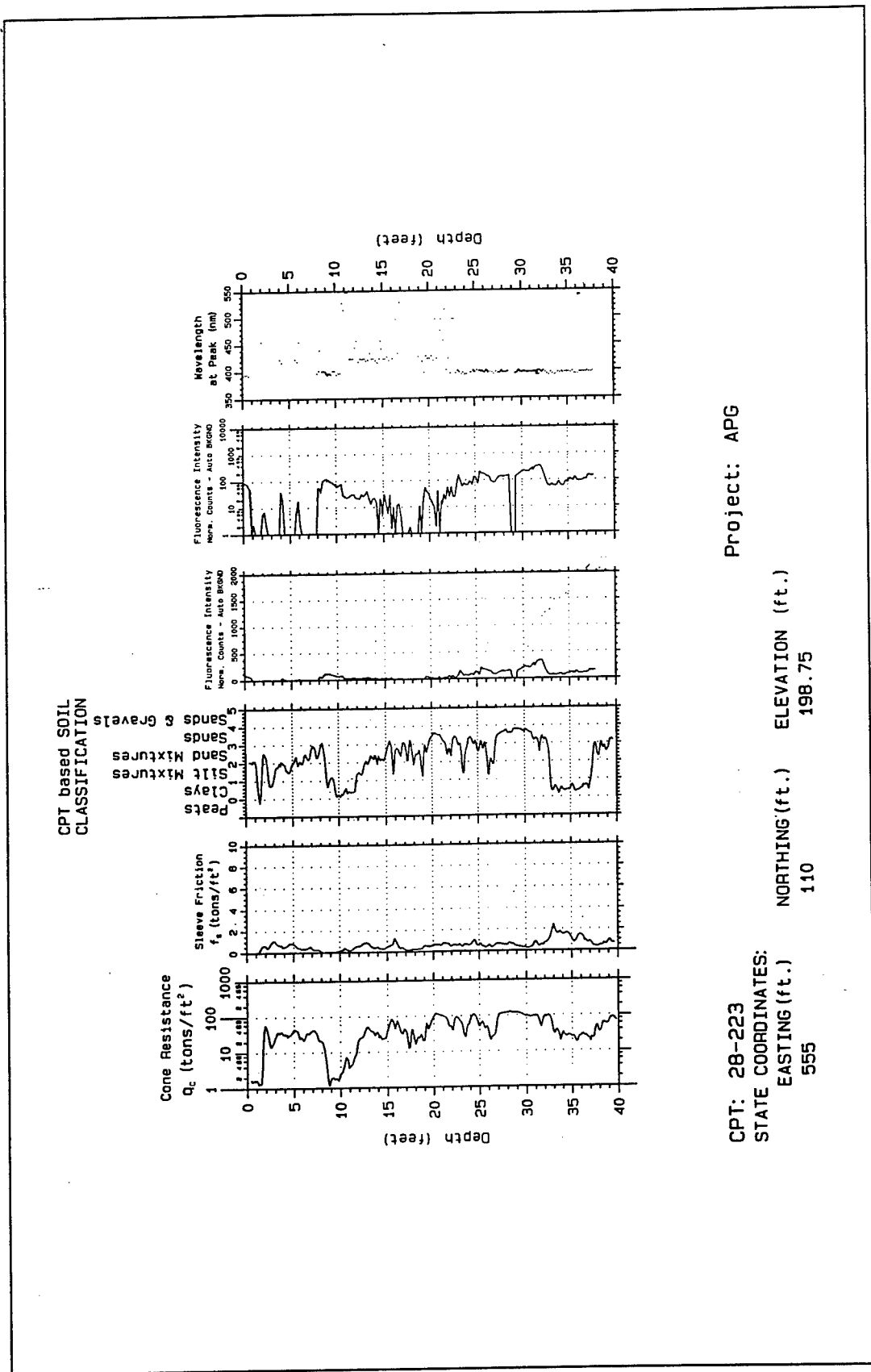


Figure A28. CPT 28-223, Aberdeen Proving Ground

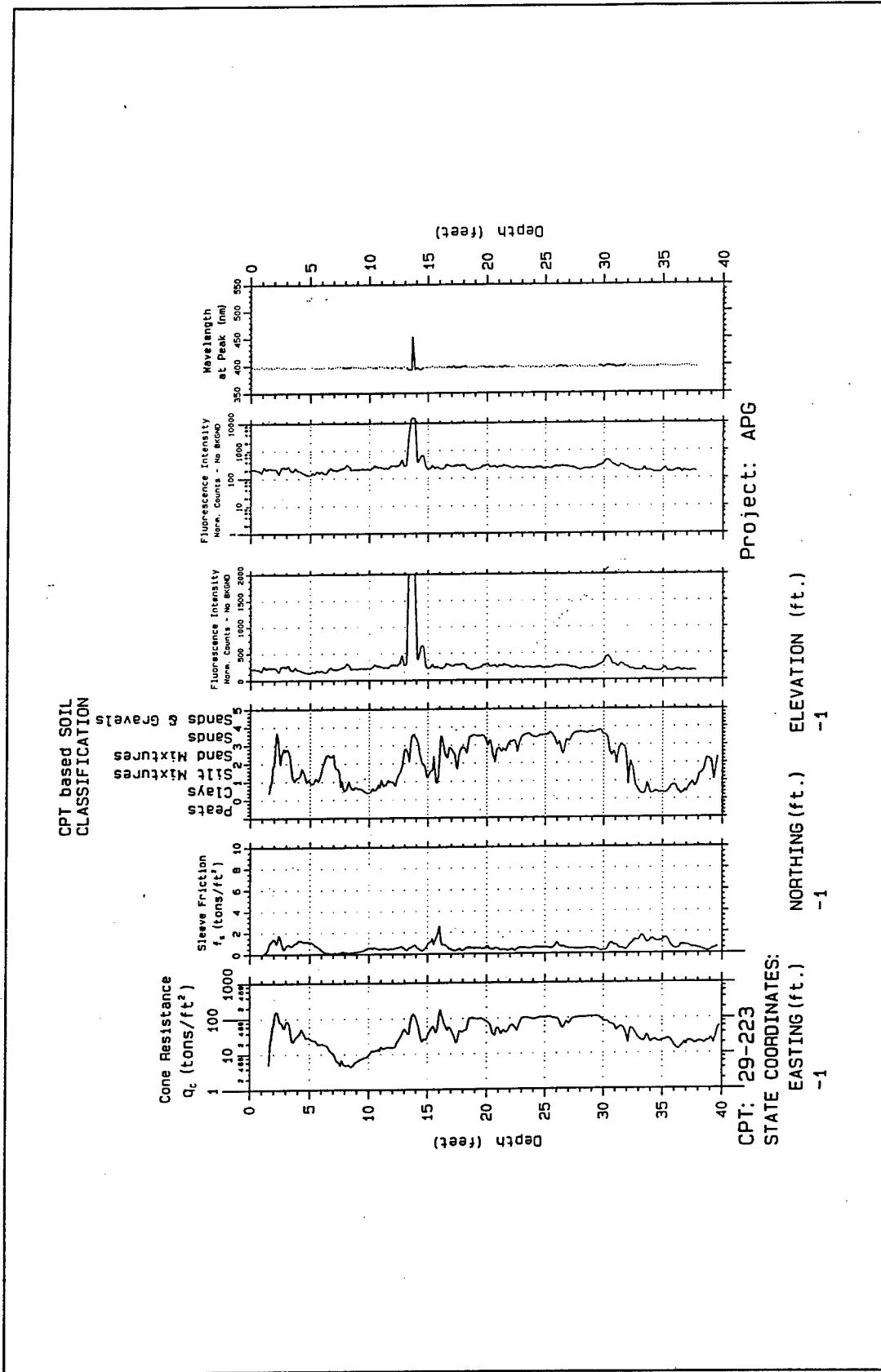


Figure A29. CPT 29-223, Aberdeen Proving Ground

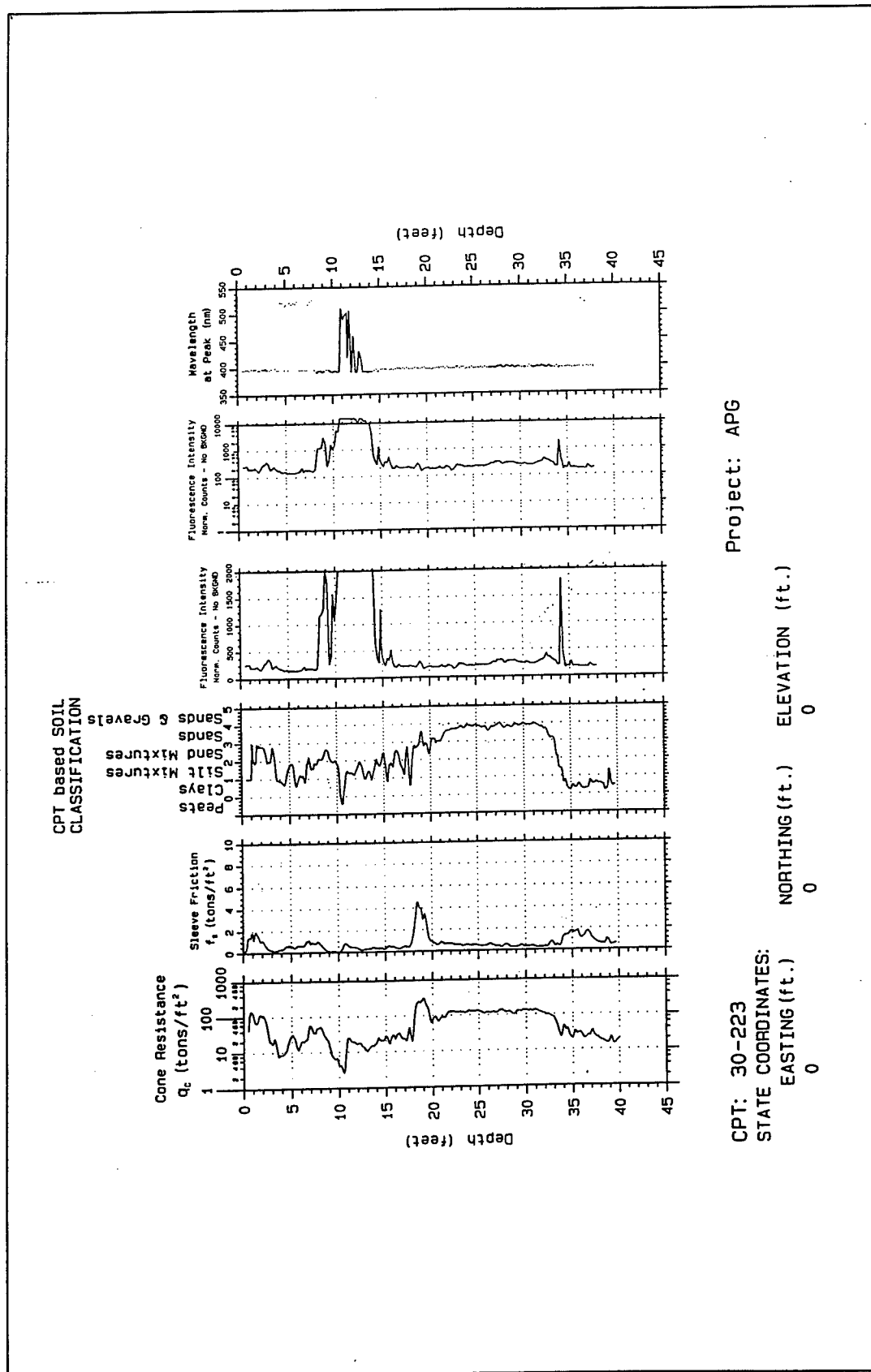


Figure A30. CPT 30-223, Aberdeen Proving Ground

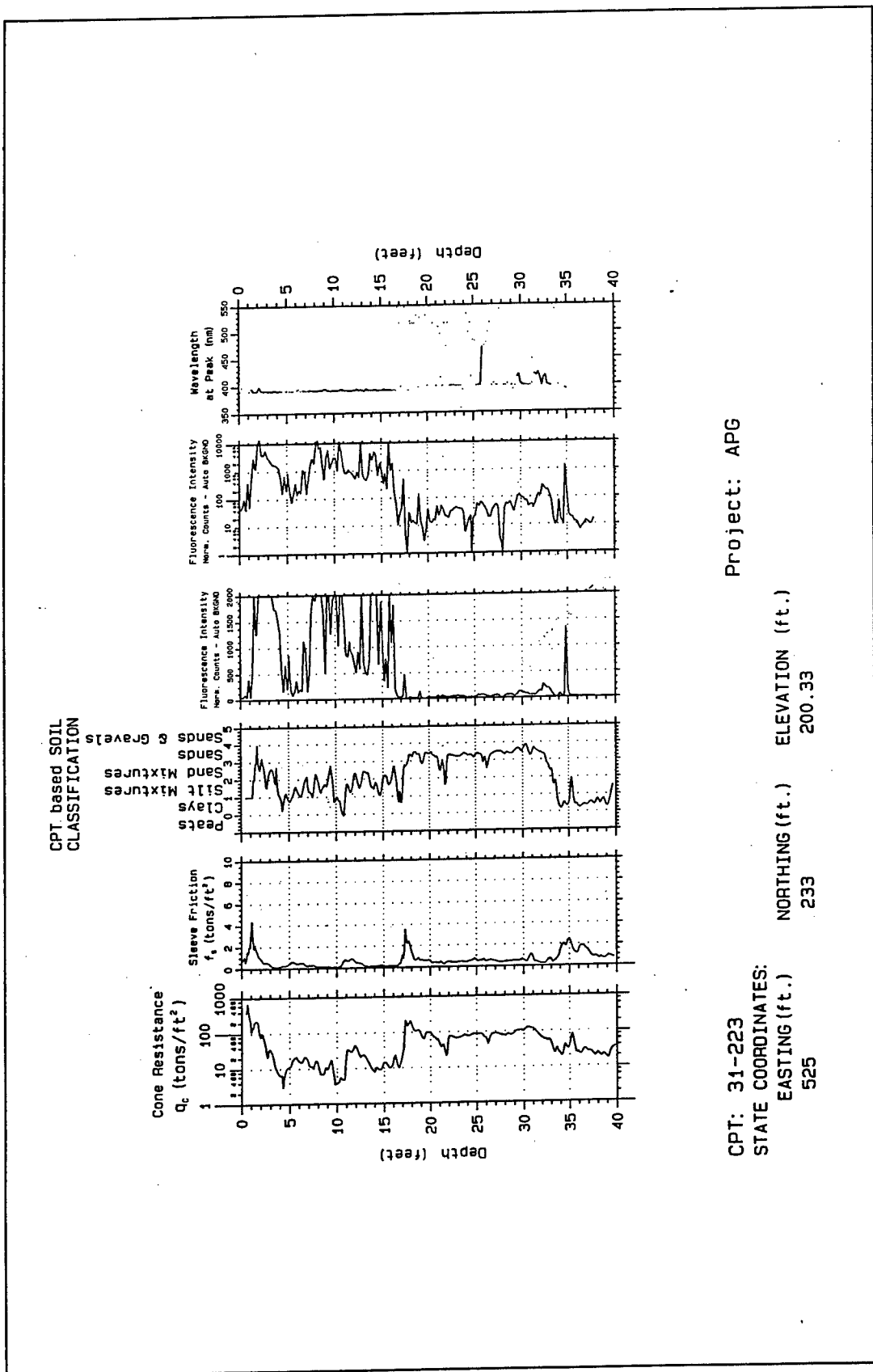


Figure A31. CPT 31-223, Aberdeen Proving Ground



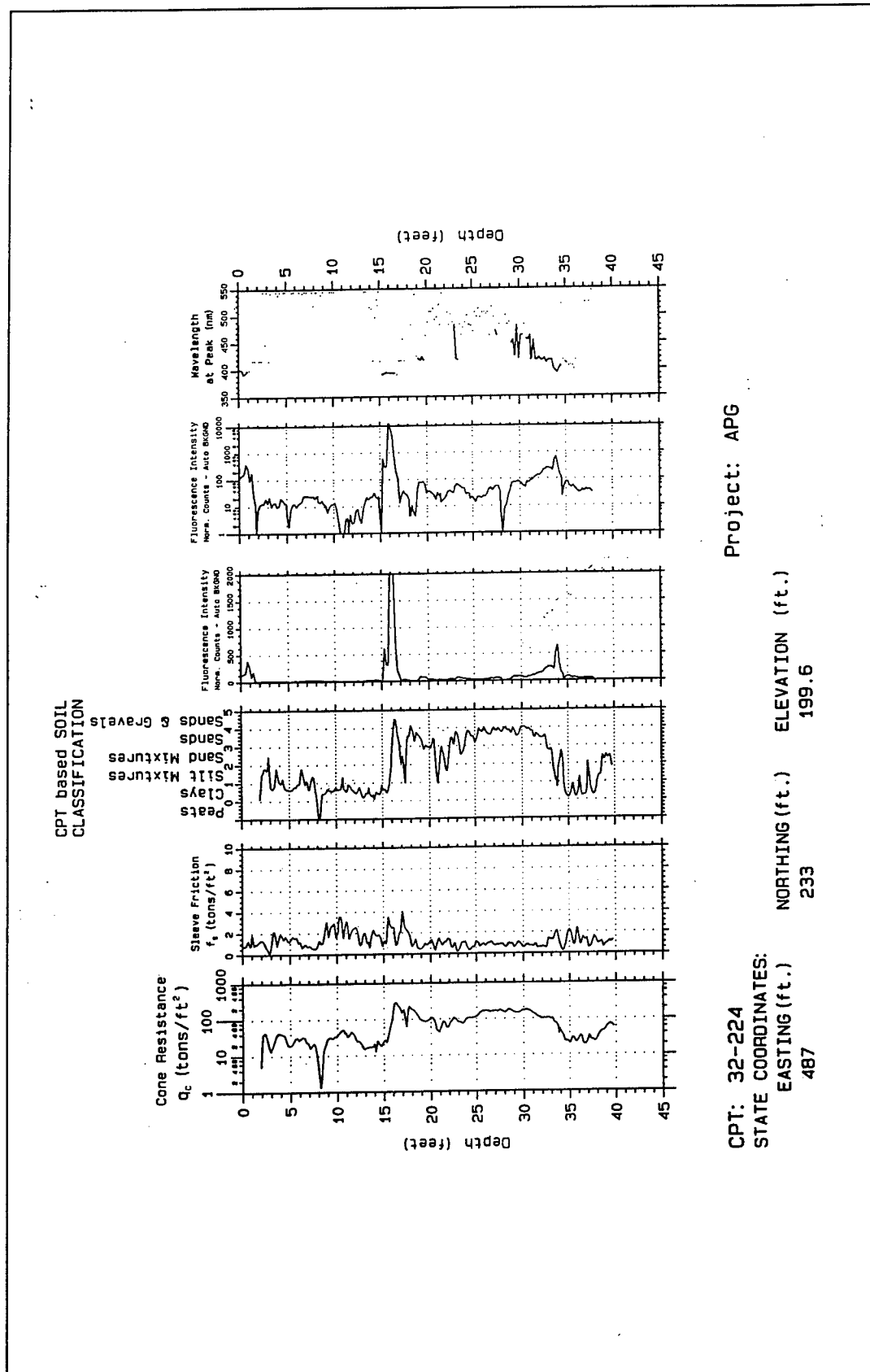


Figure A32. CPT 32-224, Aberdeen Proving Ground

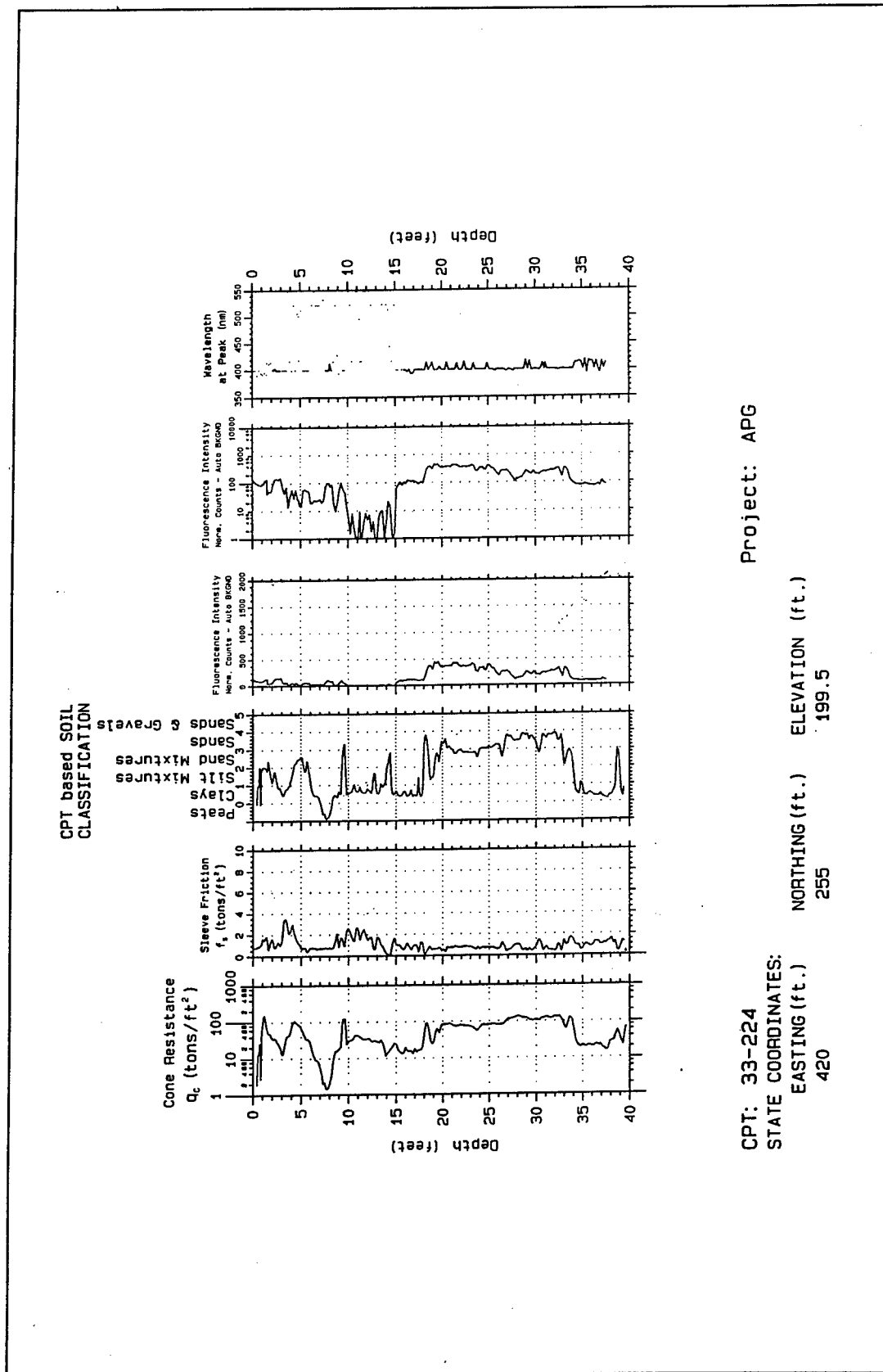


Figure A33. CPT 33-224, Aberdeen Proving Ground

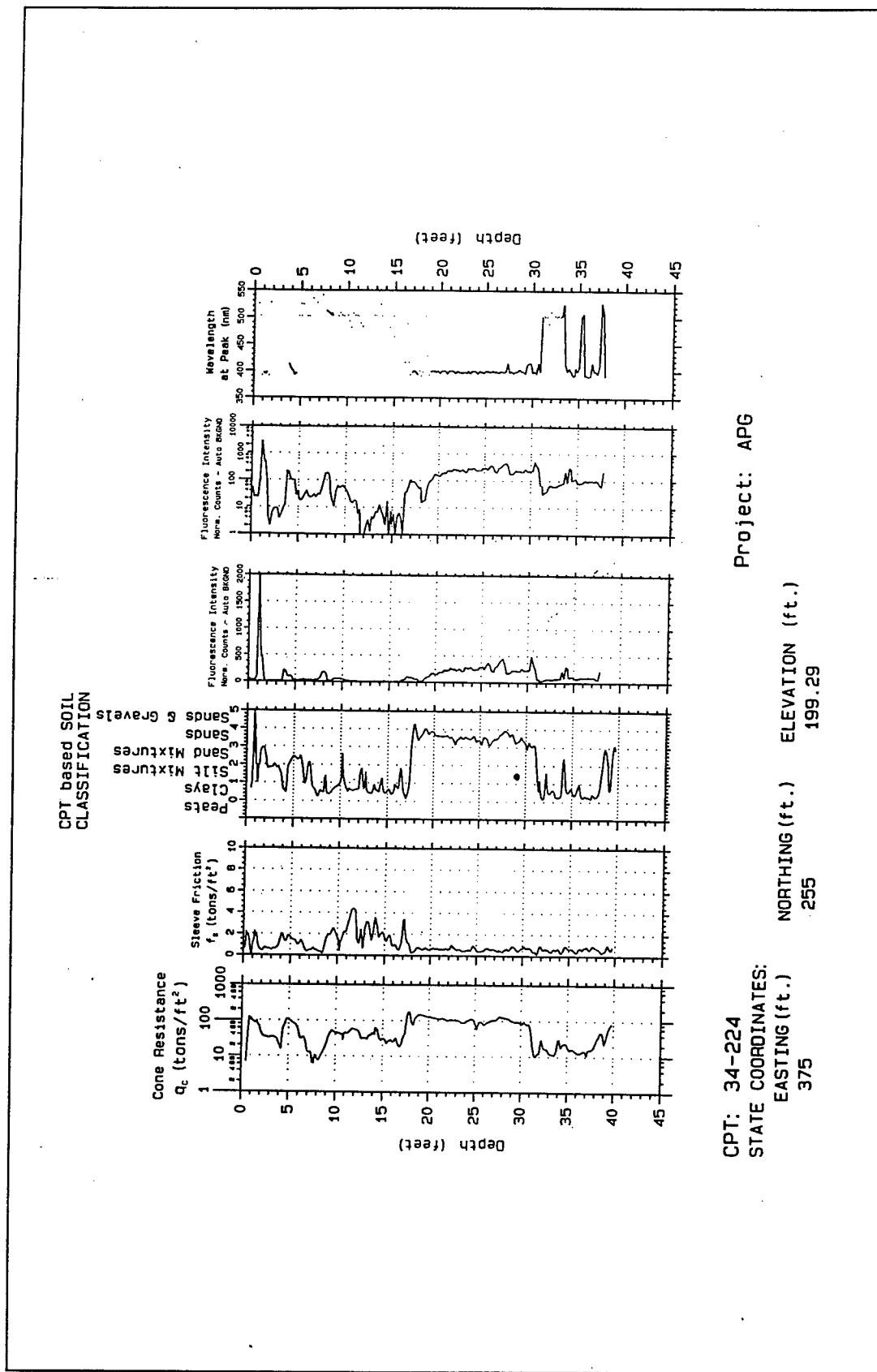


Figure A34. CPT 34-224, Aberdeen Proving Ground

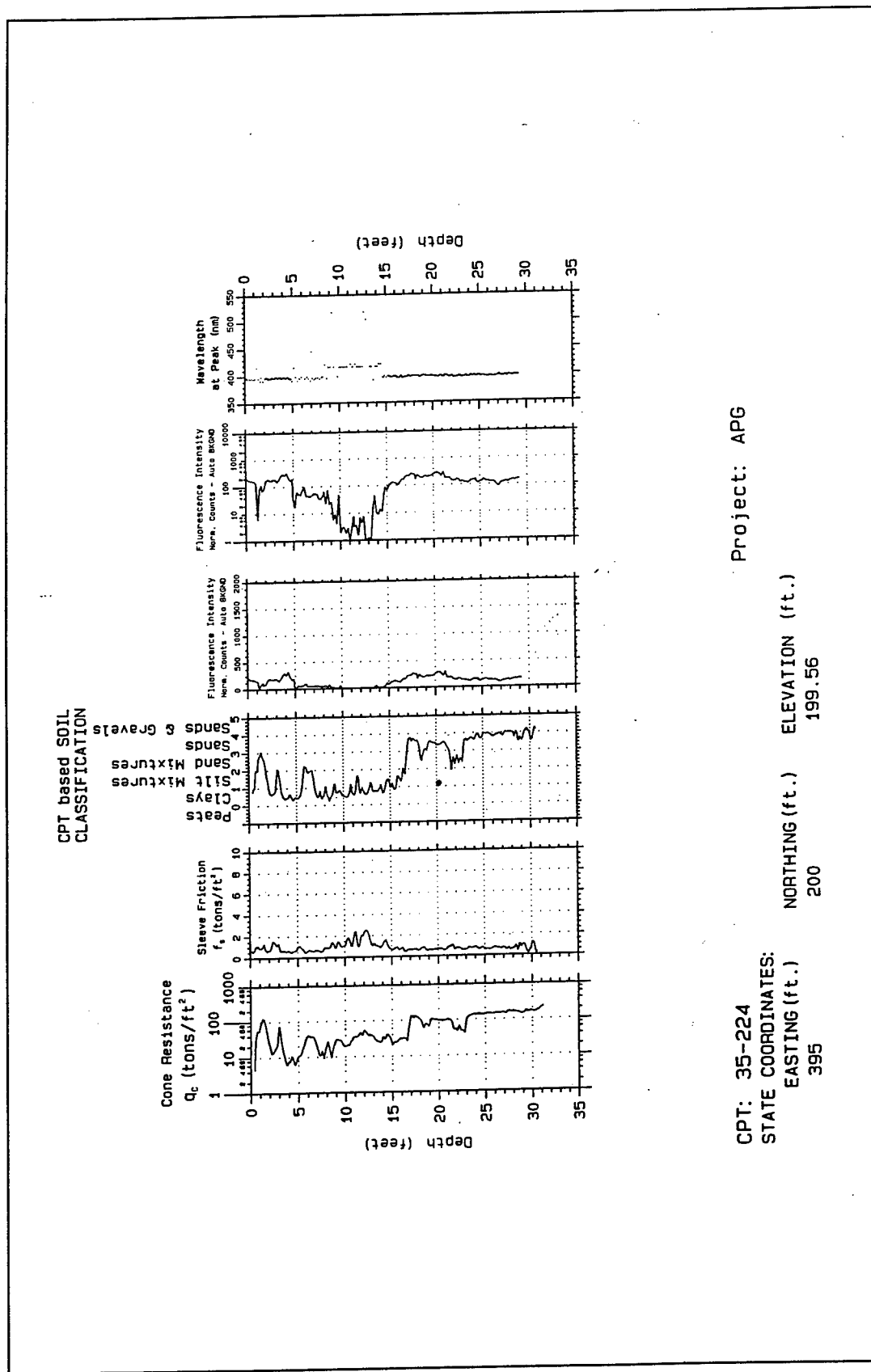
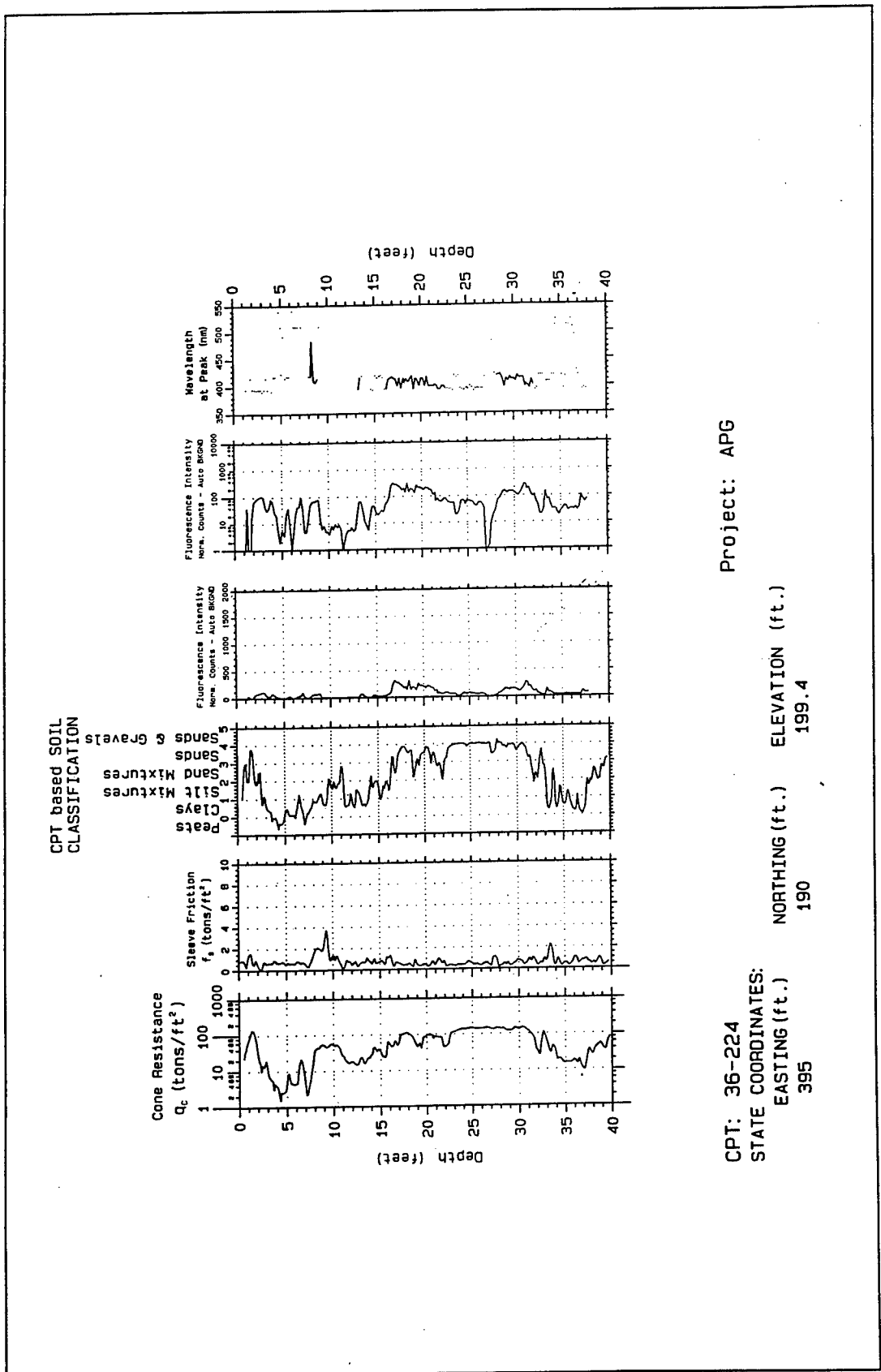


Figure A35. CPT 35-224, Aberdeen Proving Ground



Project: APG

CPT: 36-224

STATE COORDINATES:

EASTING (ft.) 395

NORTHING (ft.) 190

ELEVATION (ft.) 199.4

Figure A36. CPT 36-224, Aberdeen Proving Ground

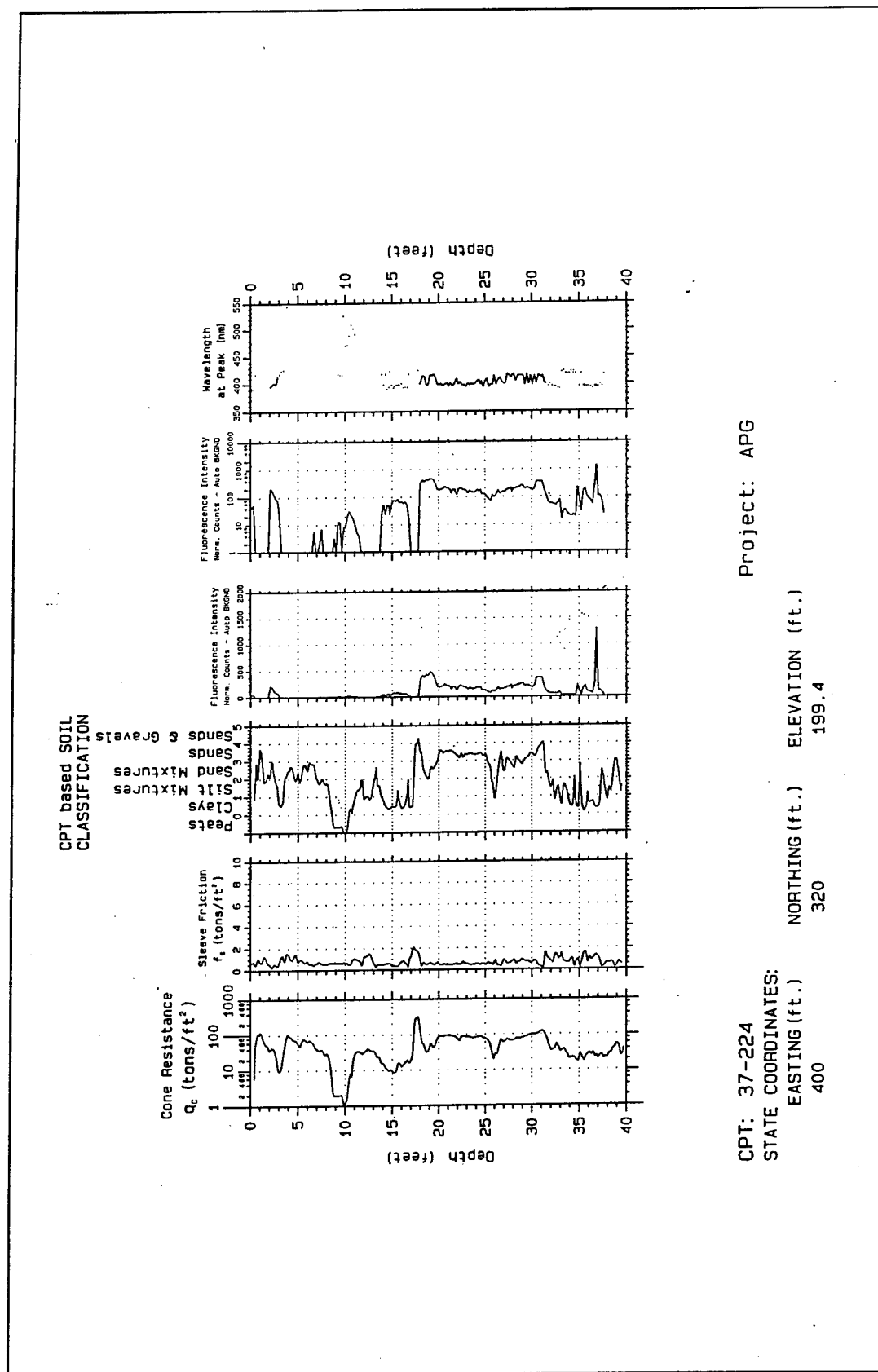


Figure A37. CPT 37-224, Aberdeen Proving Ground

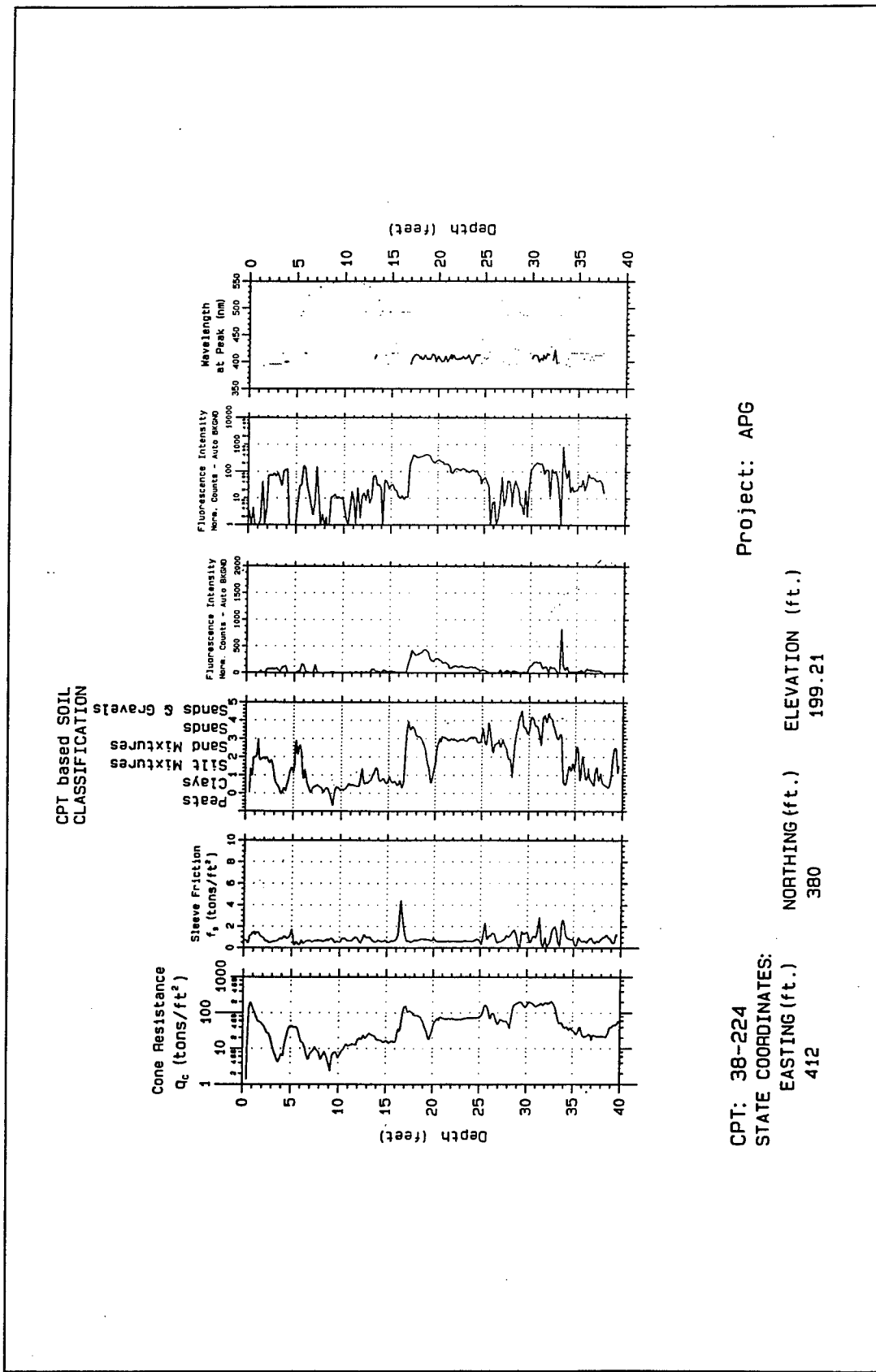


Figure A38. CPT 38-224, Aberdeen Proving Ground

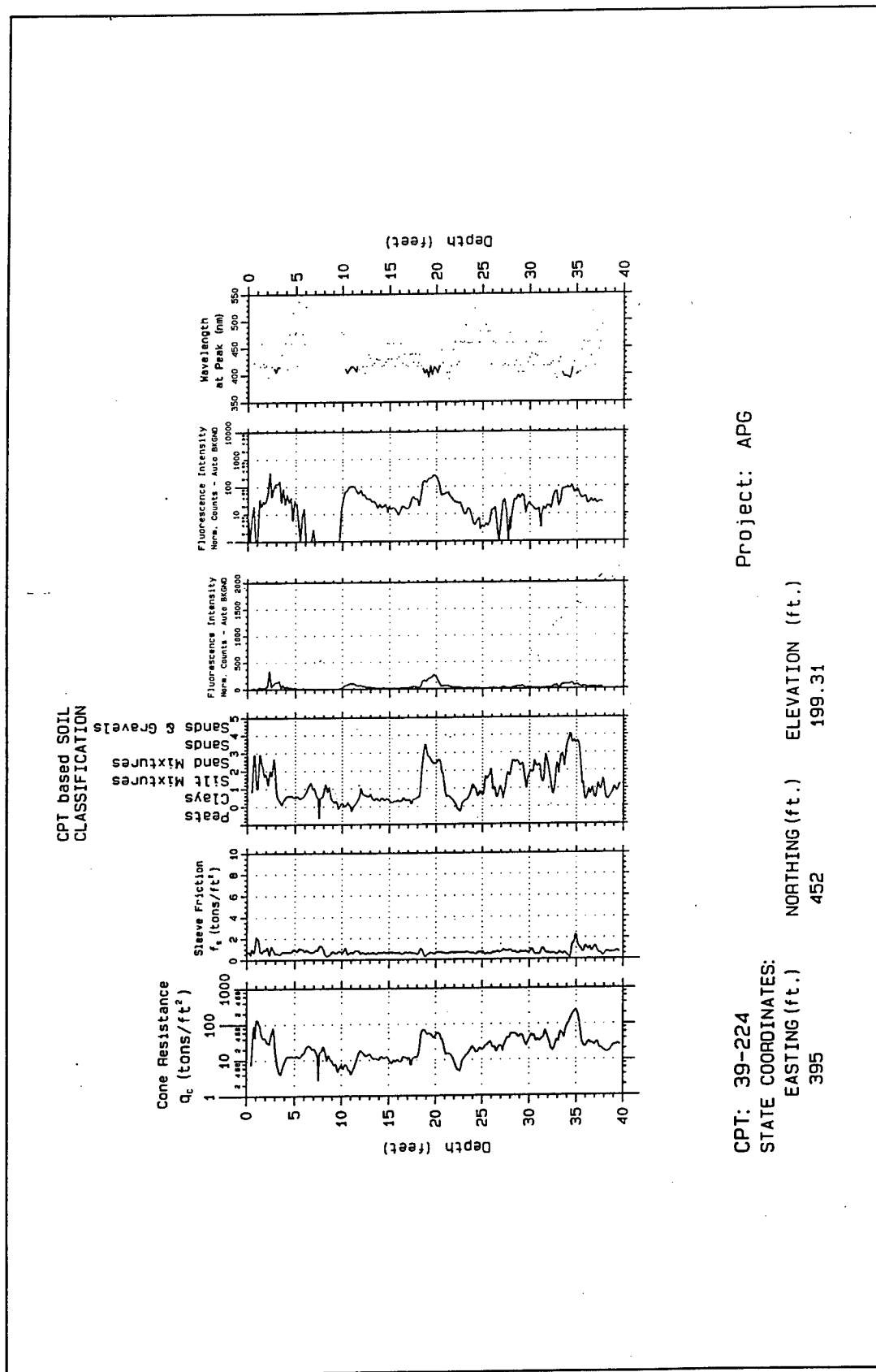


Figure A39. CPT 39-224, Aberdeen Proving Ground



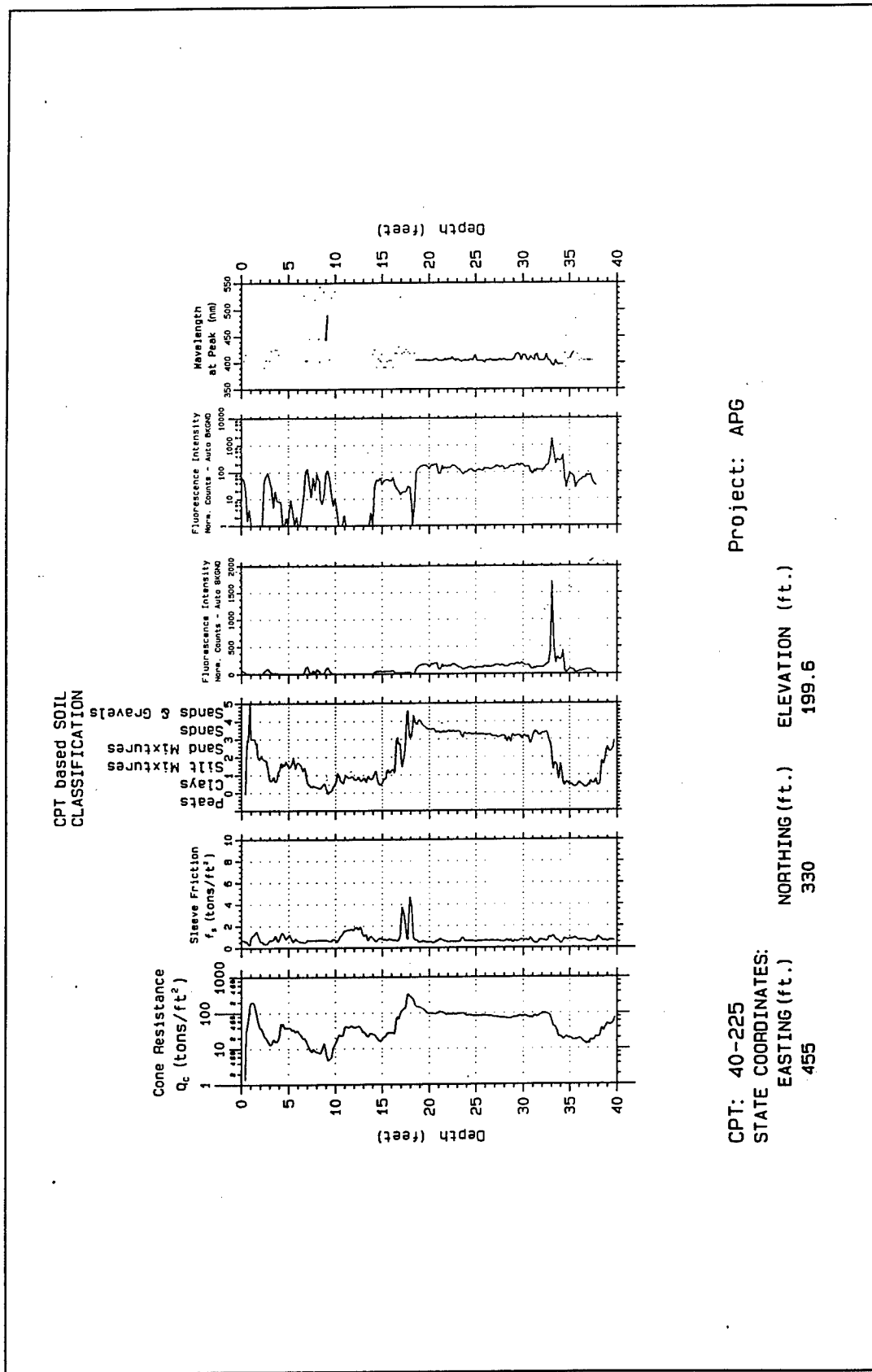
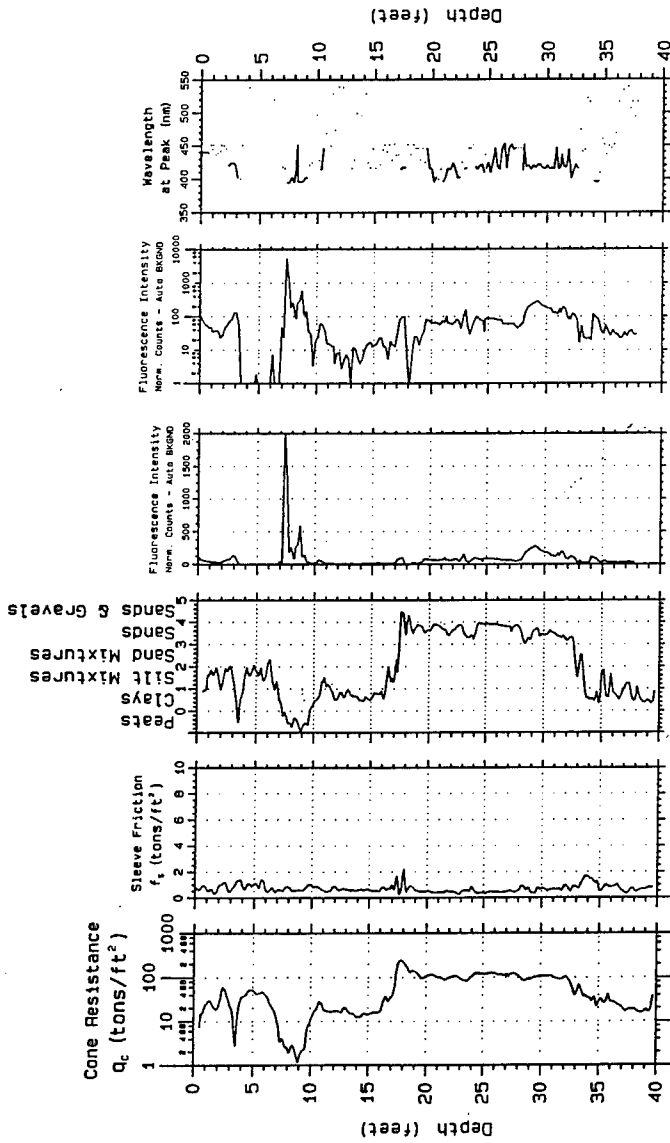


Figure A40. CPT 40-225, Aberdeen Proving Ground

CPT based SOIL  
CLASSIFICATION



CPT: 41-225  
STATE COORDINATES:  
EASTING (ft.) 530  
NORTHING (ft.) 324  
ELEVATION (ft.) 199.56  
Project: APG

Figure A41. CPT 41-225, Aberdeen Proving Ground

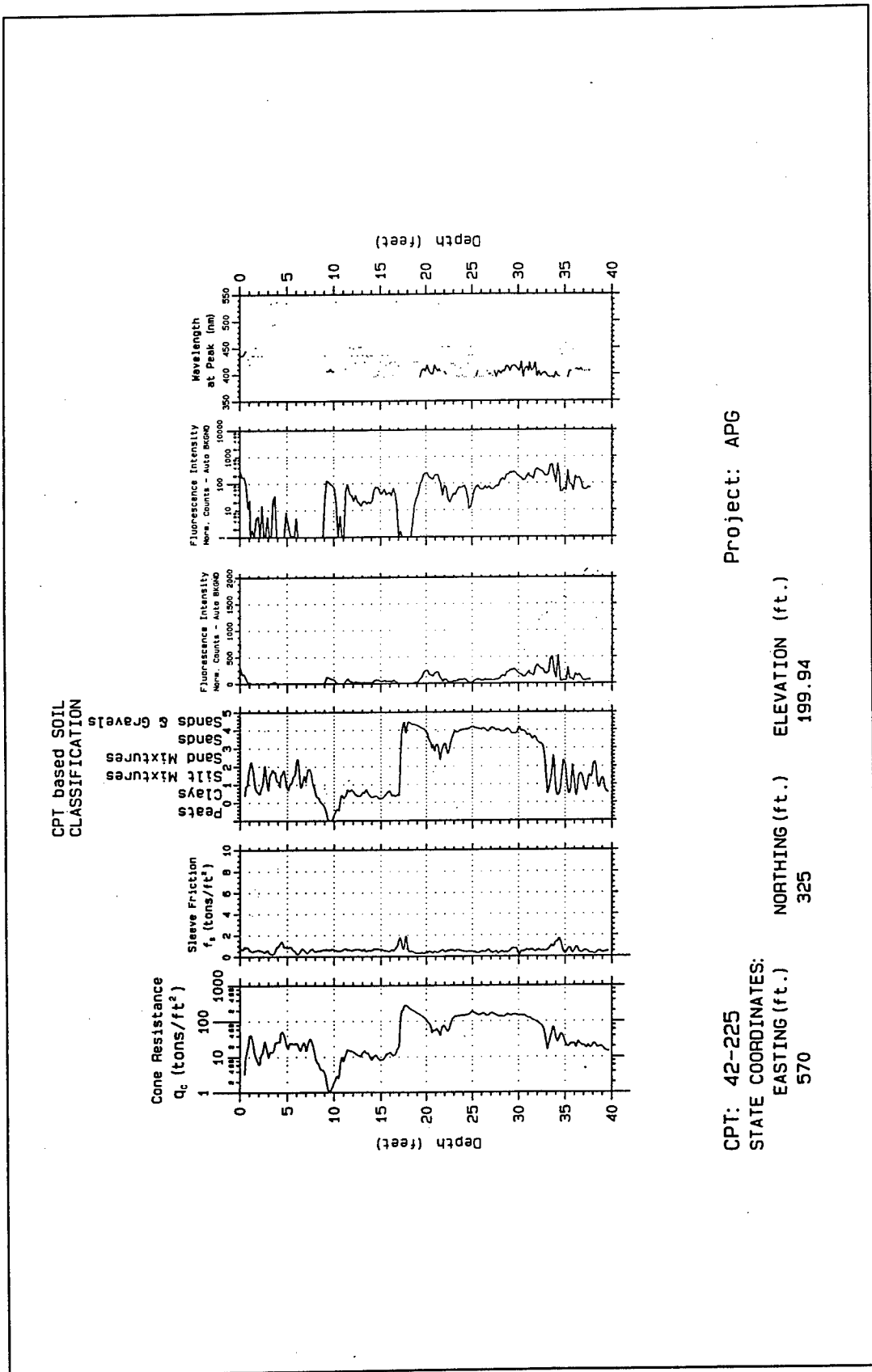


Figure A42. CPT 42-225, Aberdeen Proving Ground

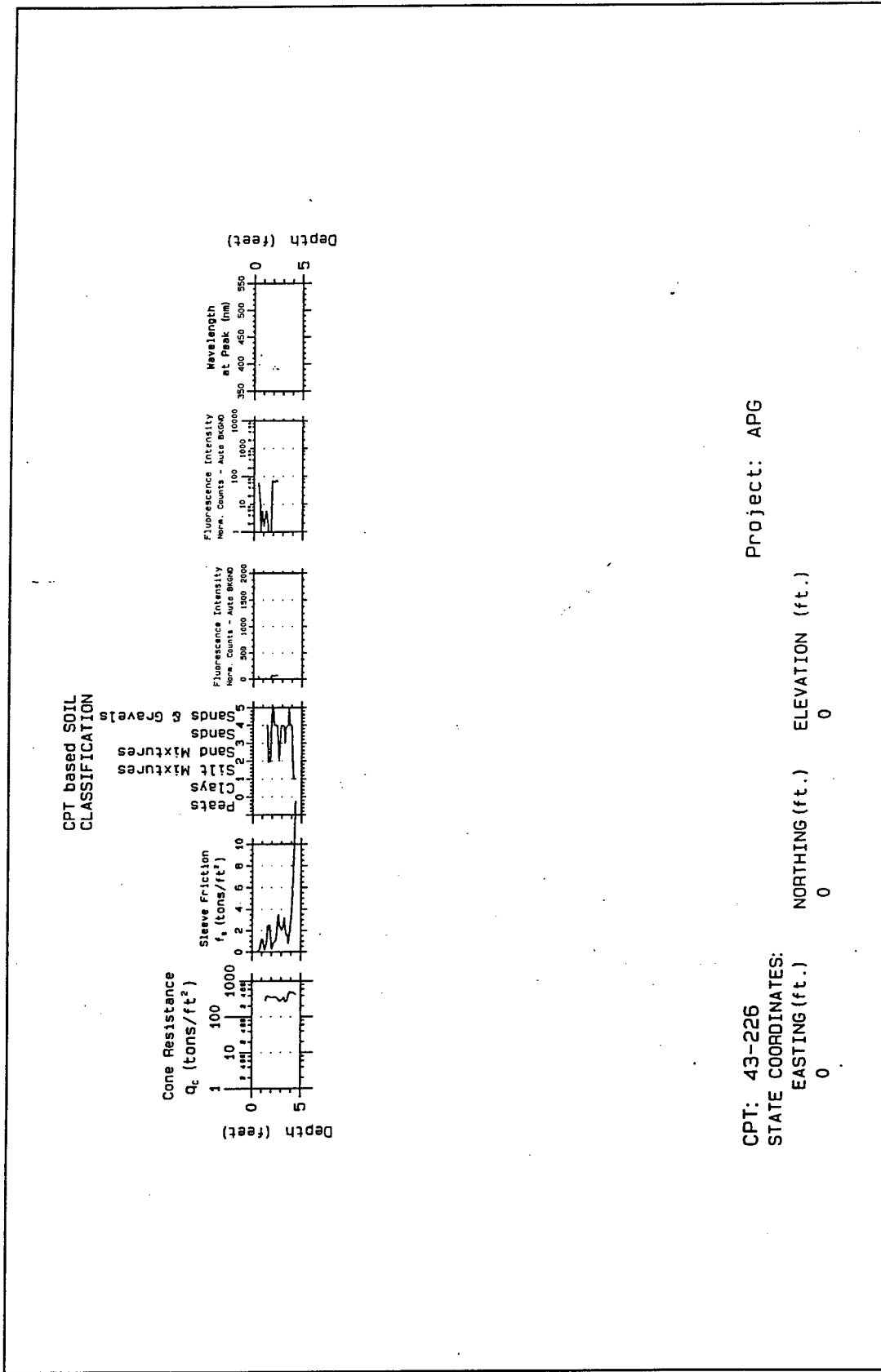


Figure A43. CPT 43-226, Aberdeen Proving Ground

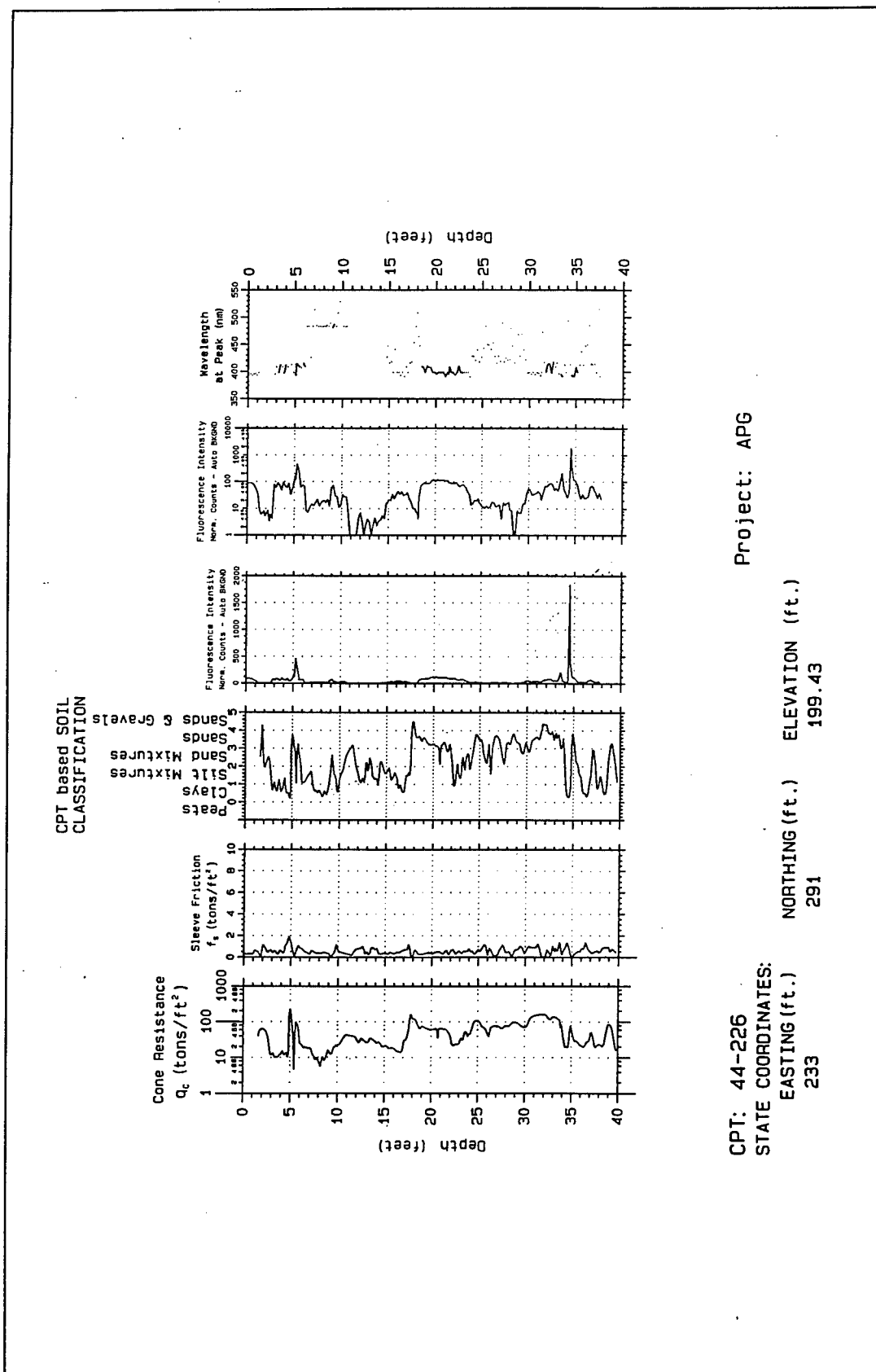


Figure A44. CPT 44-226, Aberdeen Proving Ground

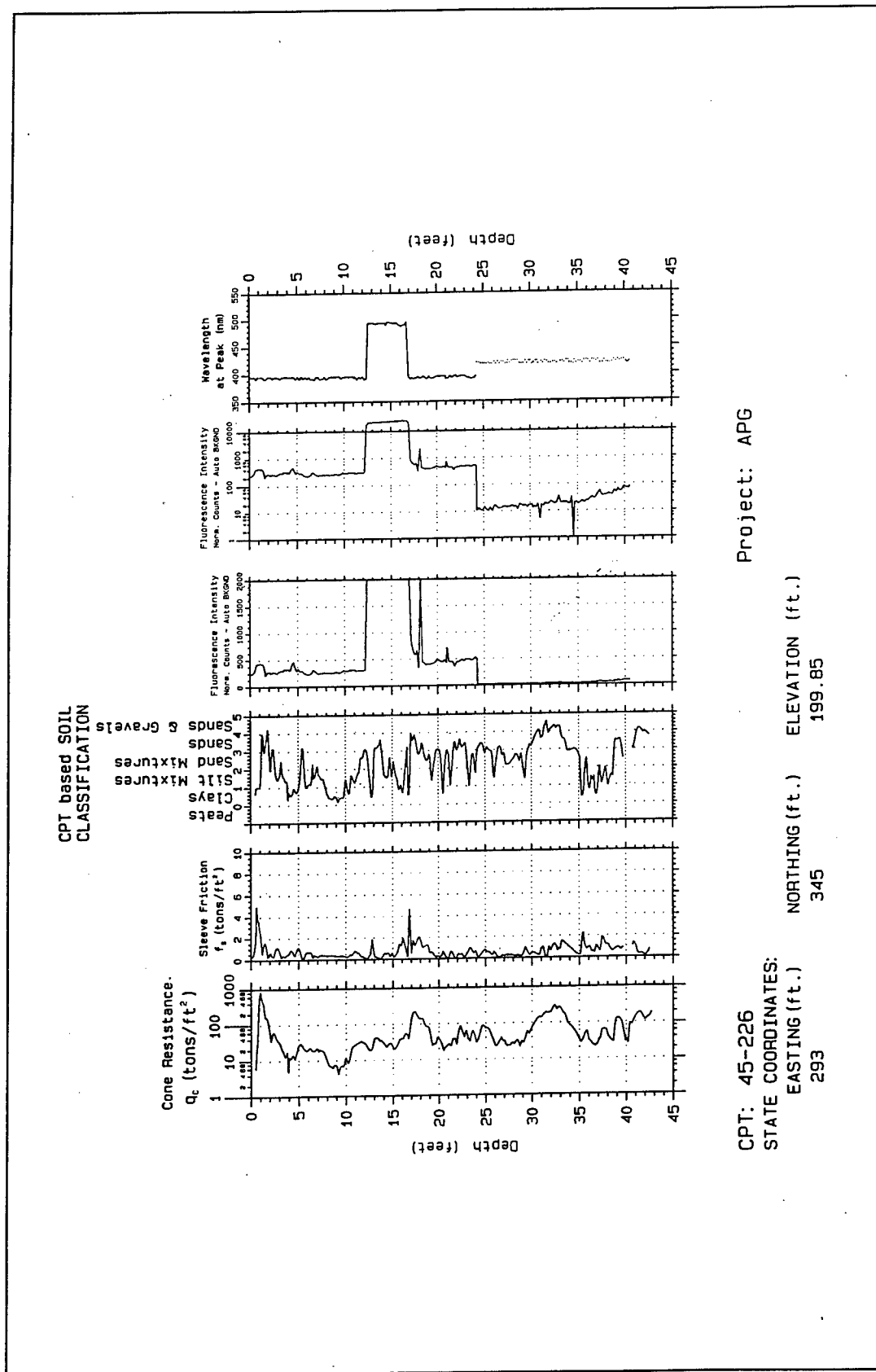


Figure A45. CPT 45-226, Aberdeen Proving Ground

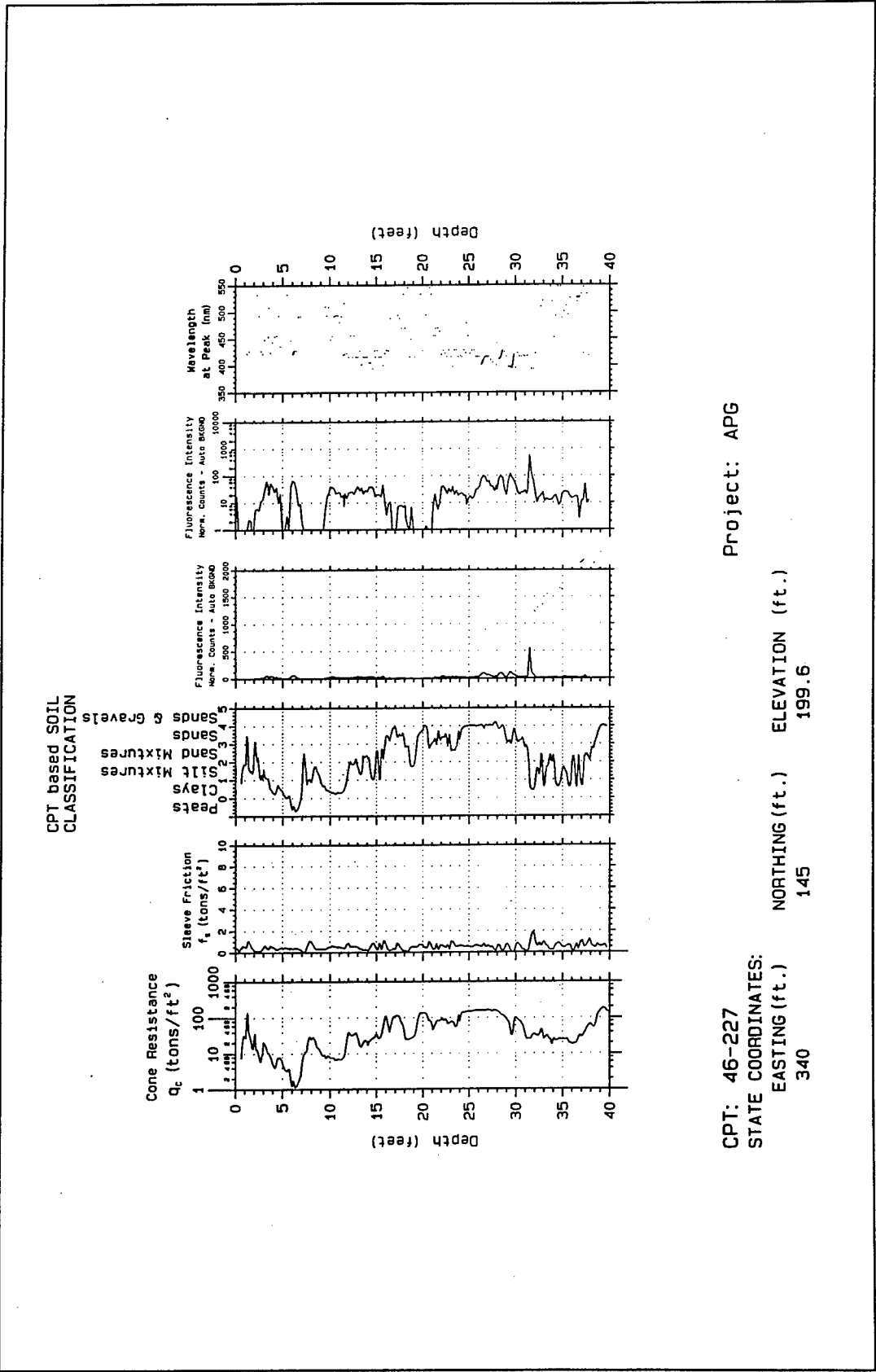


Figure A46. CPT 46-227, Aberdeen Proving Ground

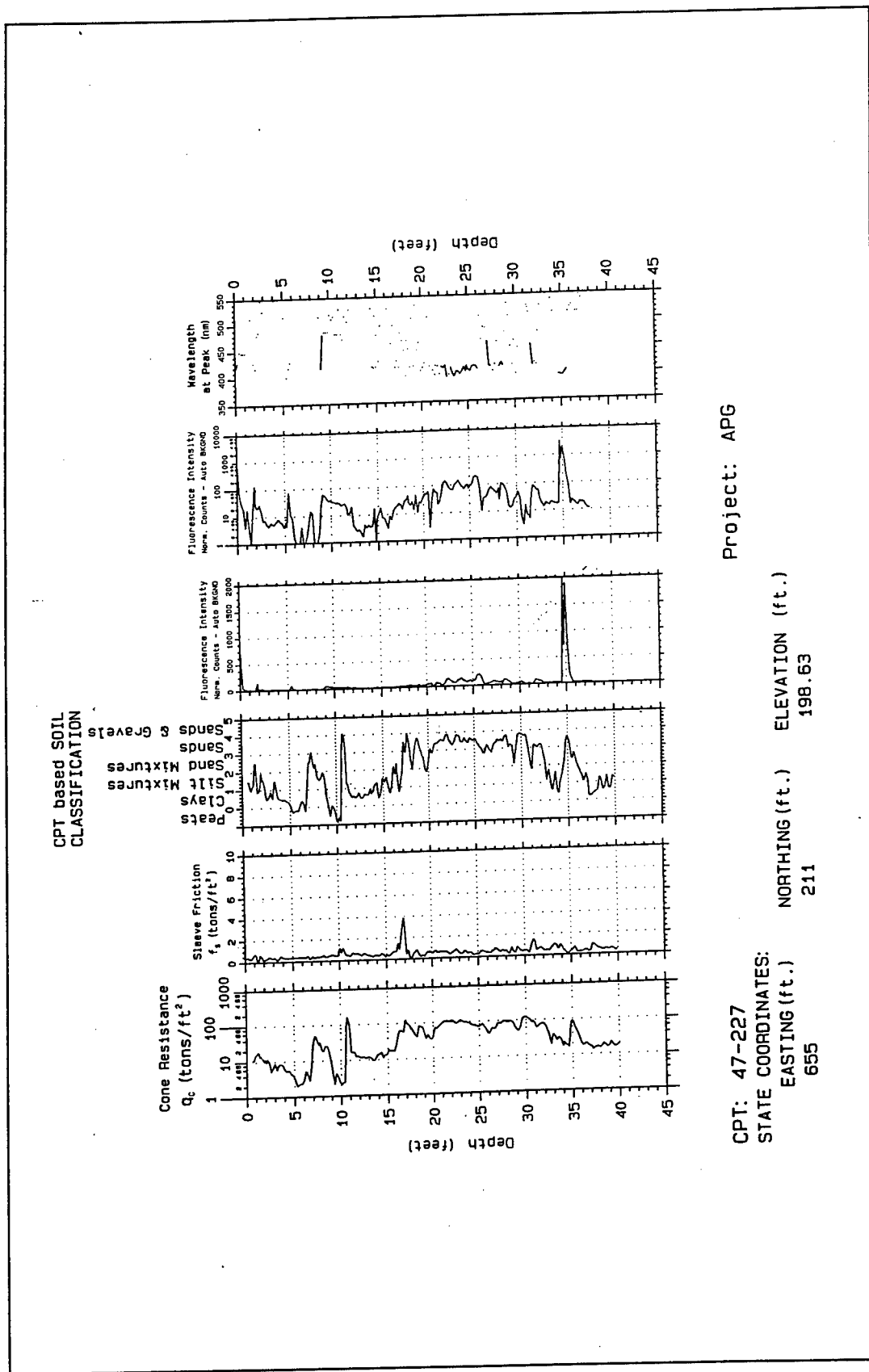


Figure A47. CPT 47-227, Aberdeen Proving Ground



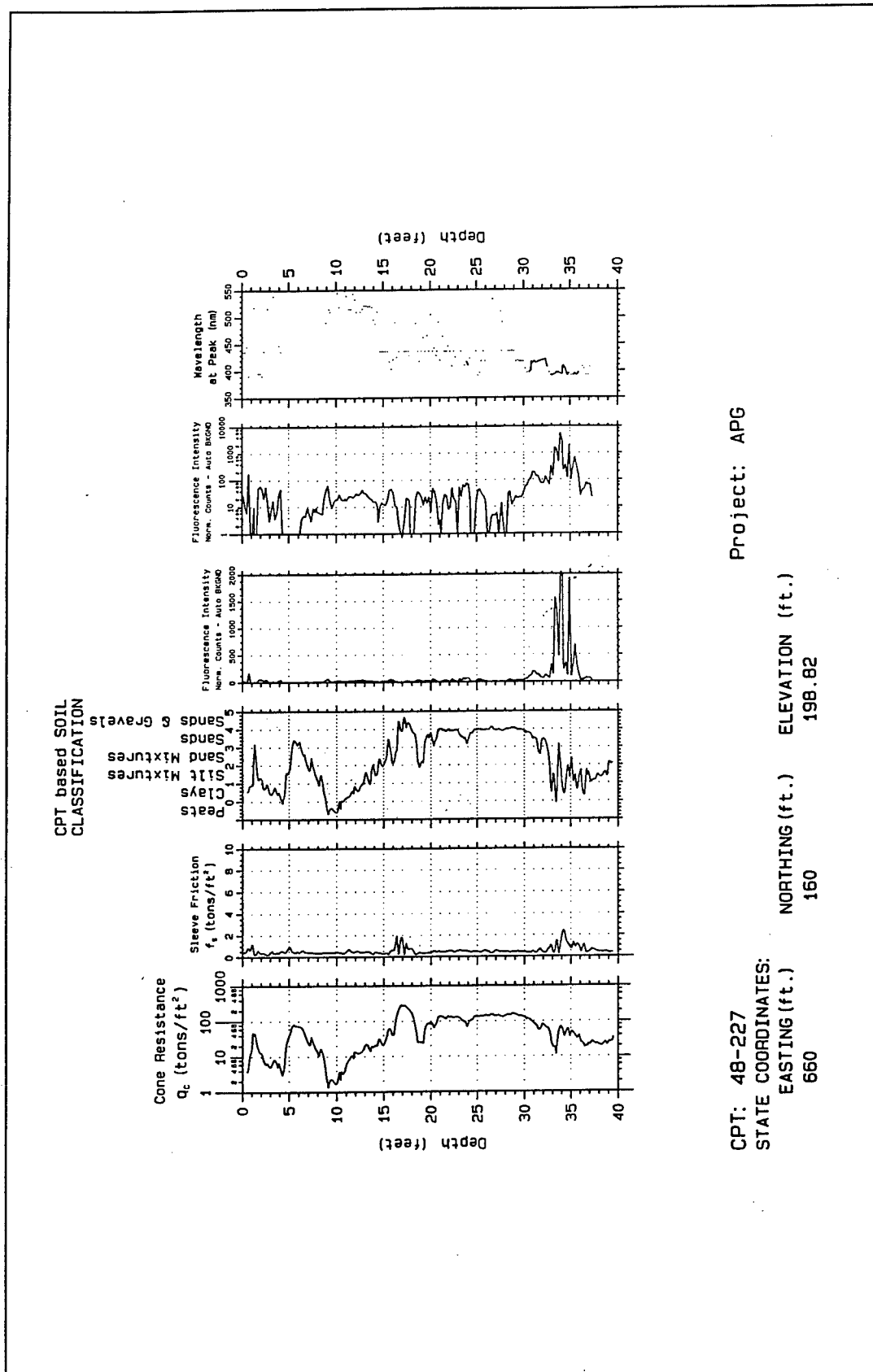


Figure A48. CPT 48-227, Aberdeen Proving Ground

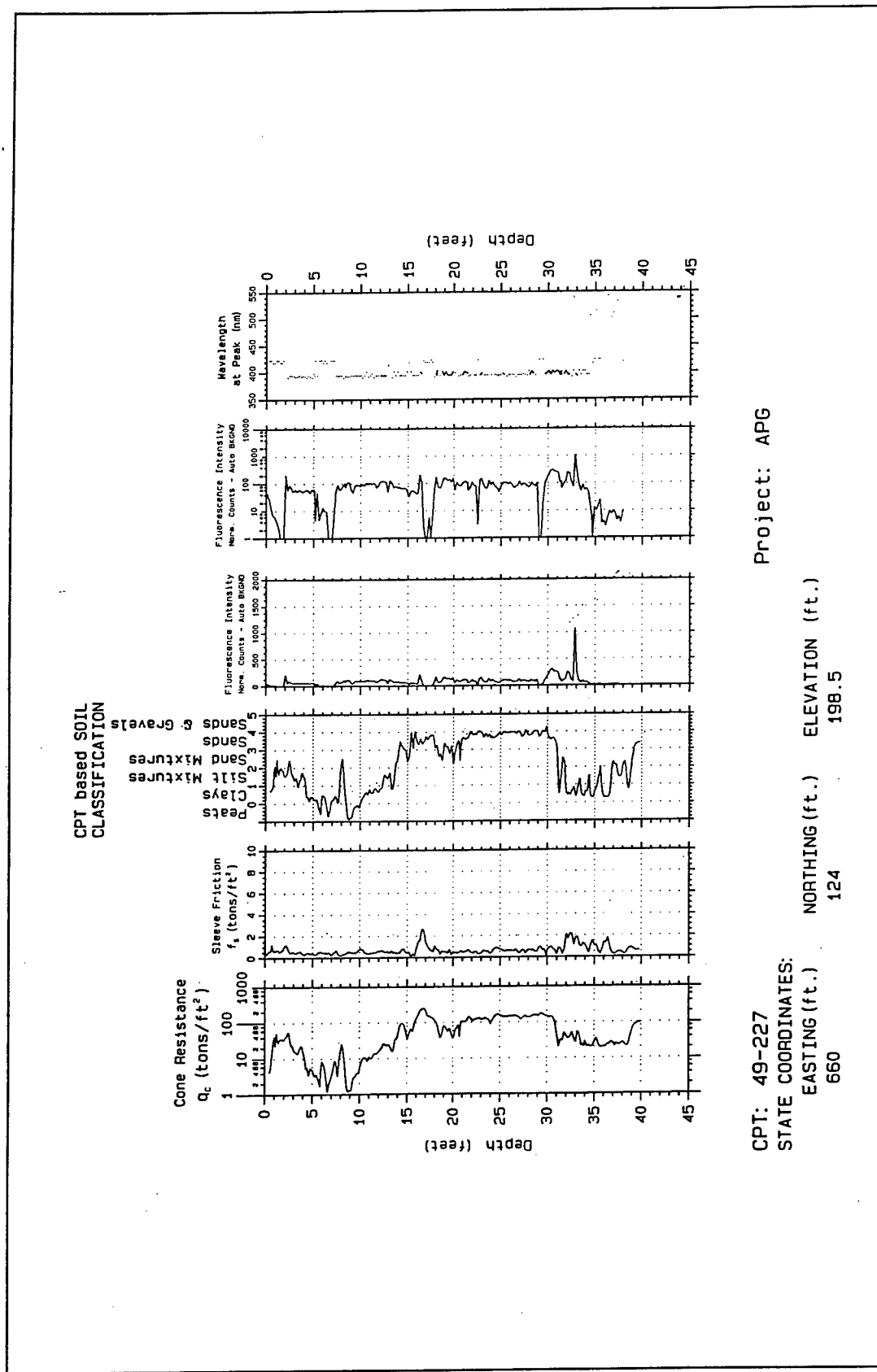


Figure A49. CPT 49-227, Aberdeen Proving Ground

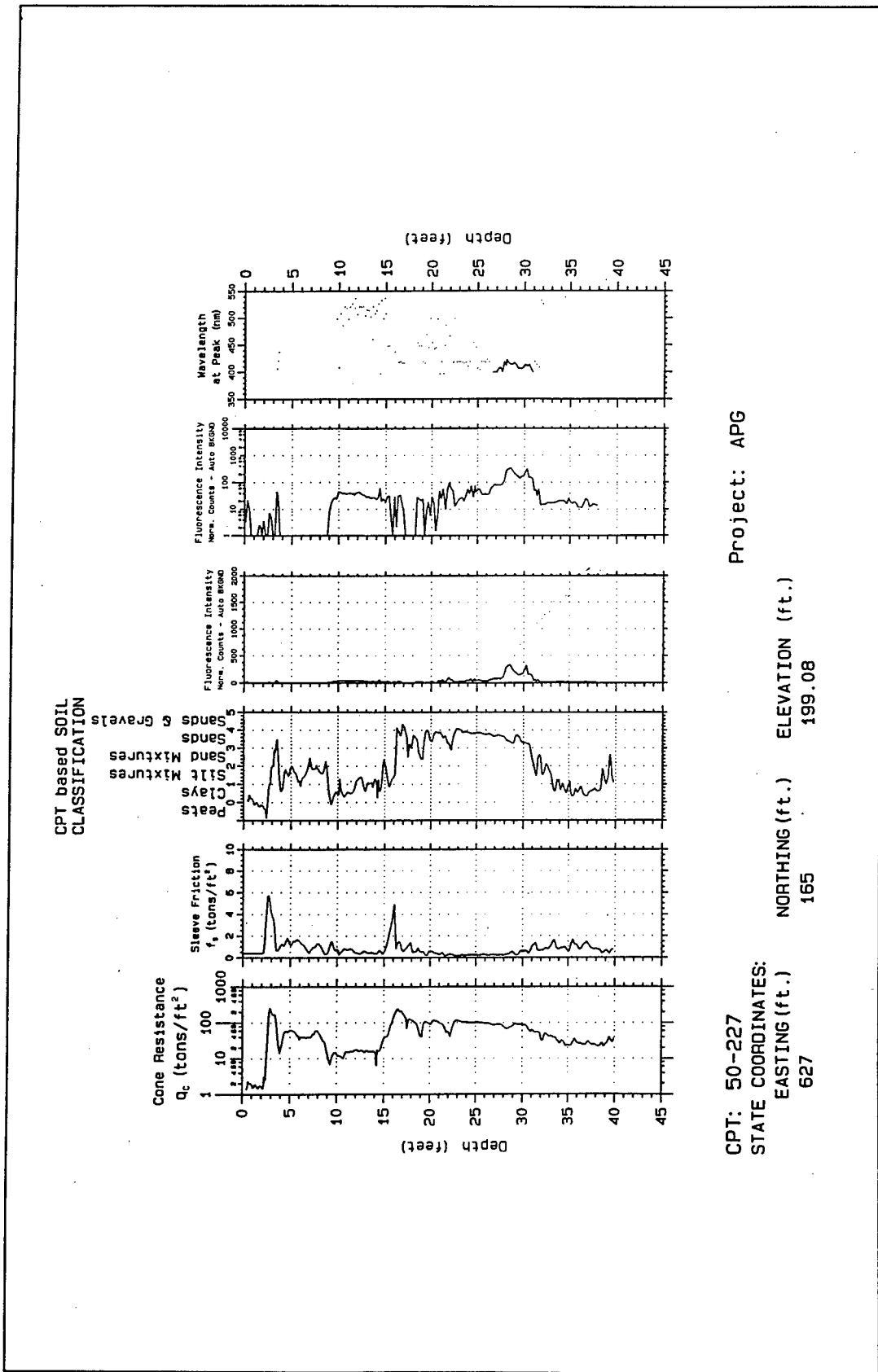


Figure A50. CPT 50-227, Aberdeen Proving Ground

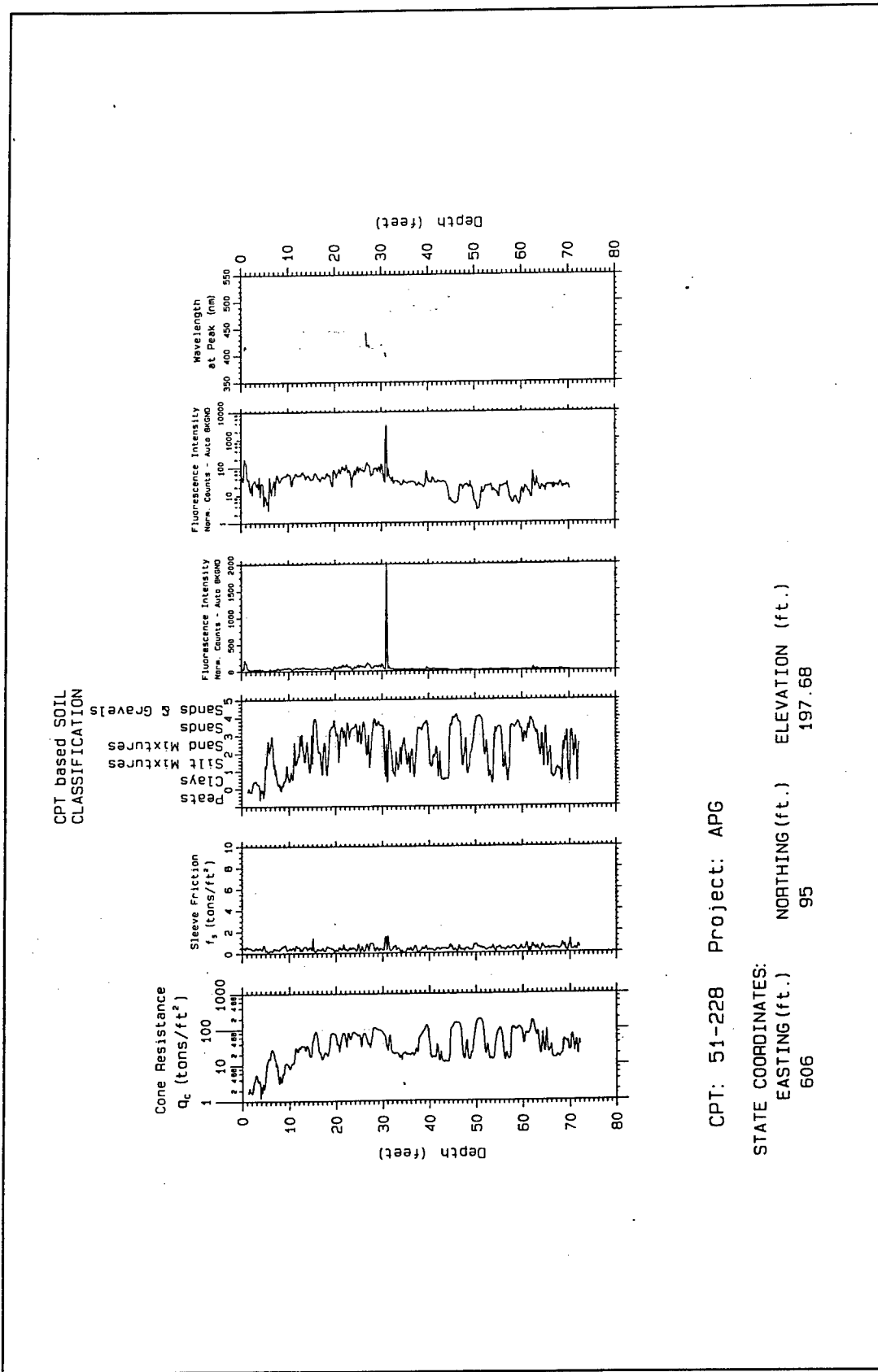


Figure A51. CPT 51-228, Aberdeen Proving Ground

# **Appendix B**

## **List of Demonstration**

### **Participants**

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**APG SCAPS DEMO**  
**01 and 02 March 1995**

Name	Organization	Phone
Jennifer Cook	USAEC	
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# REPORT DOCUMENTATION PAGE

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6. AUTHOR(S) William M. Davis, Landris T. Lee, Jr., Jeff F. Powell					
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Engineer Waterways Experiment Station 3909 Halls Ferry Road Vicksburg, MS 39180-6199				8. PERFORMING ORGANIZATION REPORT NUMBER Technical Report EL-96-17	
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14. SUBJECT TERMS Cone penetrometer Contamination plume mapping Field and laboratory verification  Laser-induced fluorometer POL contamination Soil stratigraphy				15. NUMBER OF PAGES 92	
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